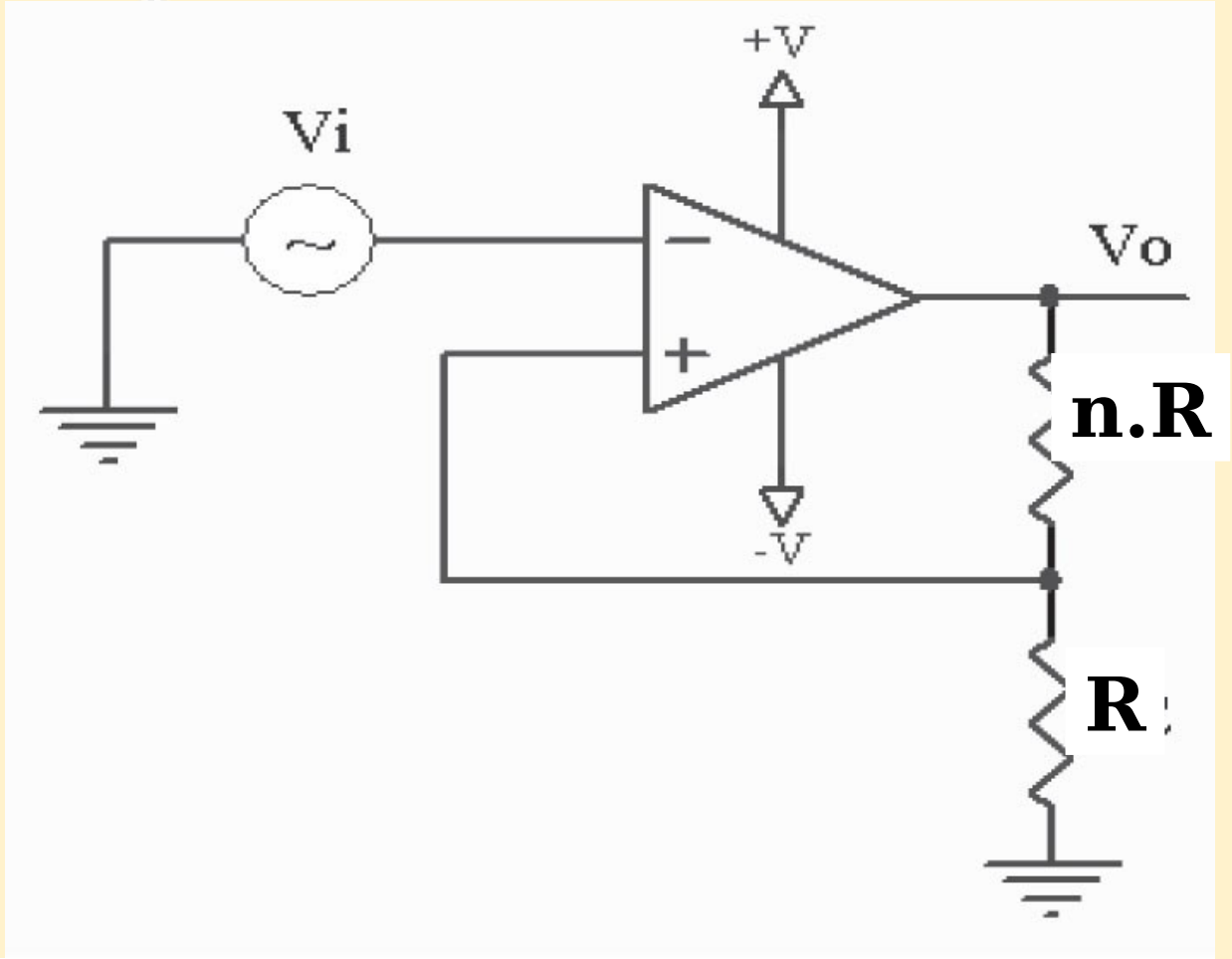
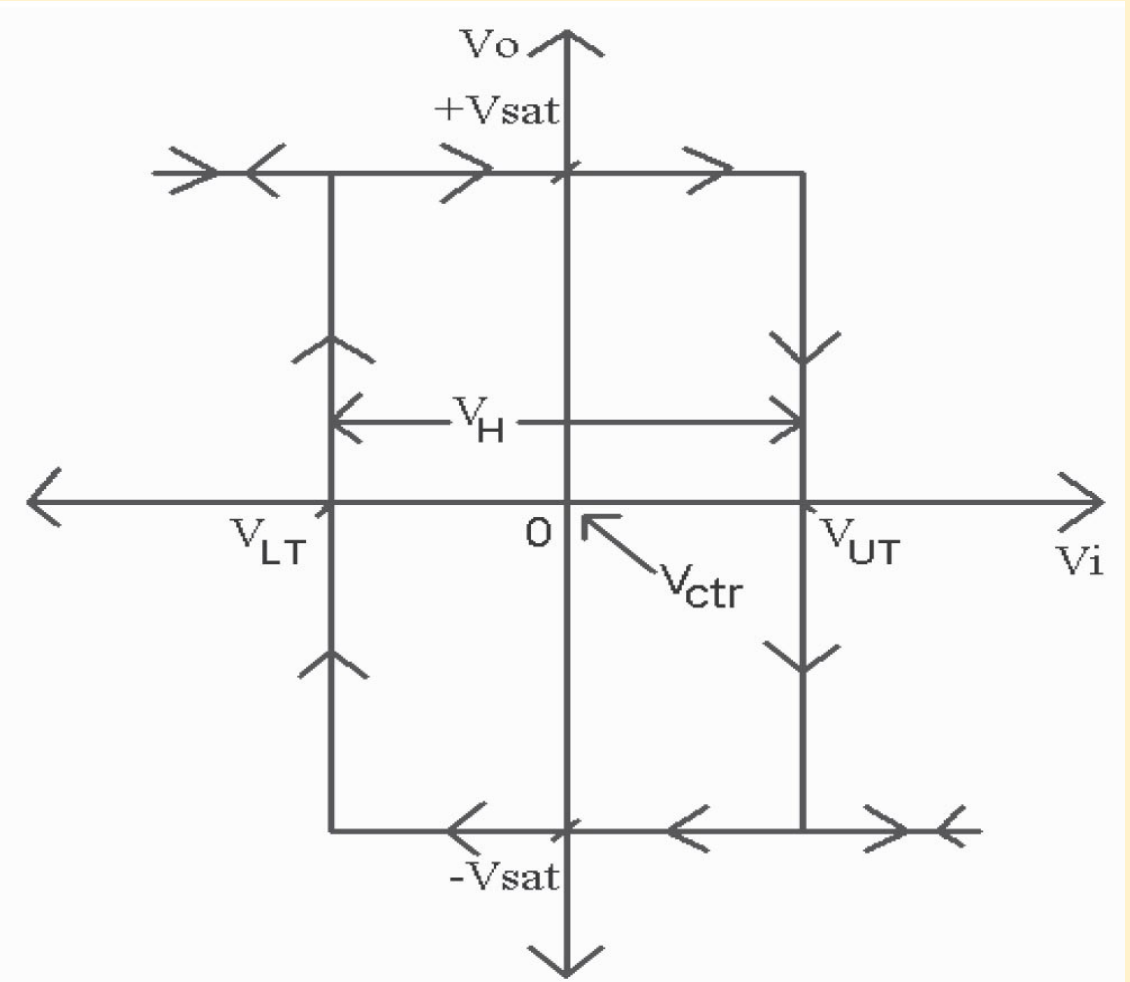
INVERTING ZERO CROSSING DETECTOR WITH HYSTERESIS



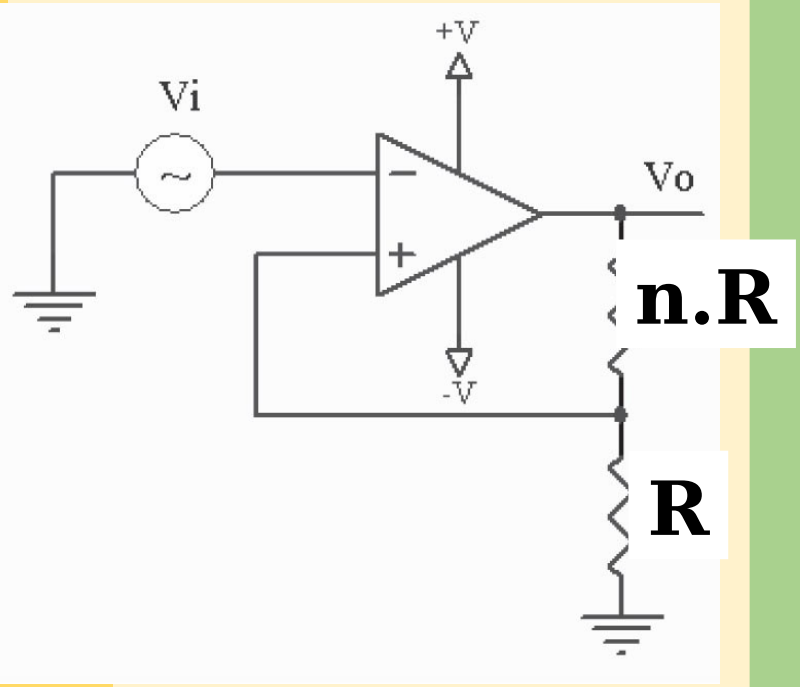
Rangkaian Inverting zero crossing detector dengan hiterisis



Karakteristik input-output dari IZCD dengan histerisis

$$Vin = \frac{R}{R + n.R} . (Vout)$$

$$Vin = \frac{Vout}{1 + n}$$



$$VLT = \frac{-Vsat}{1 + n}$$

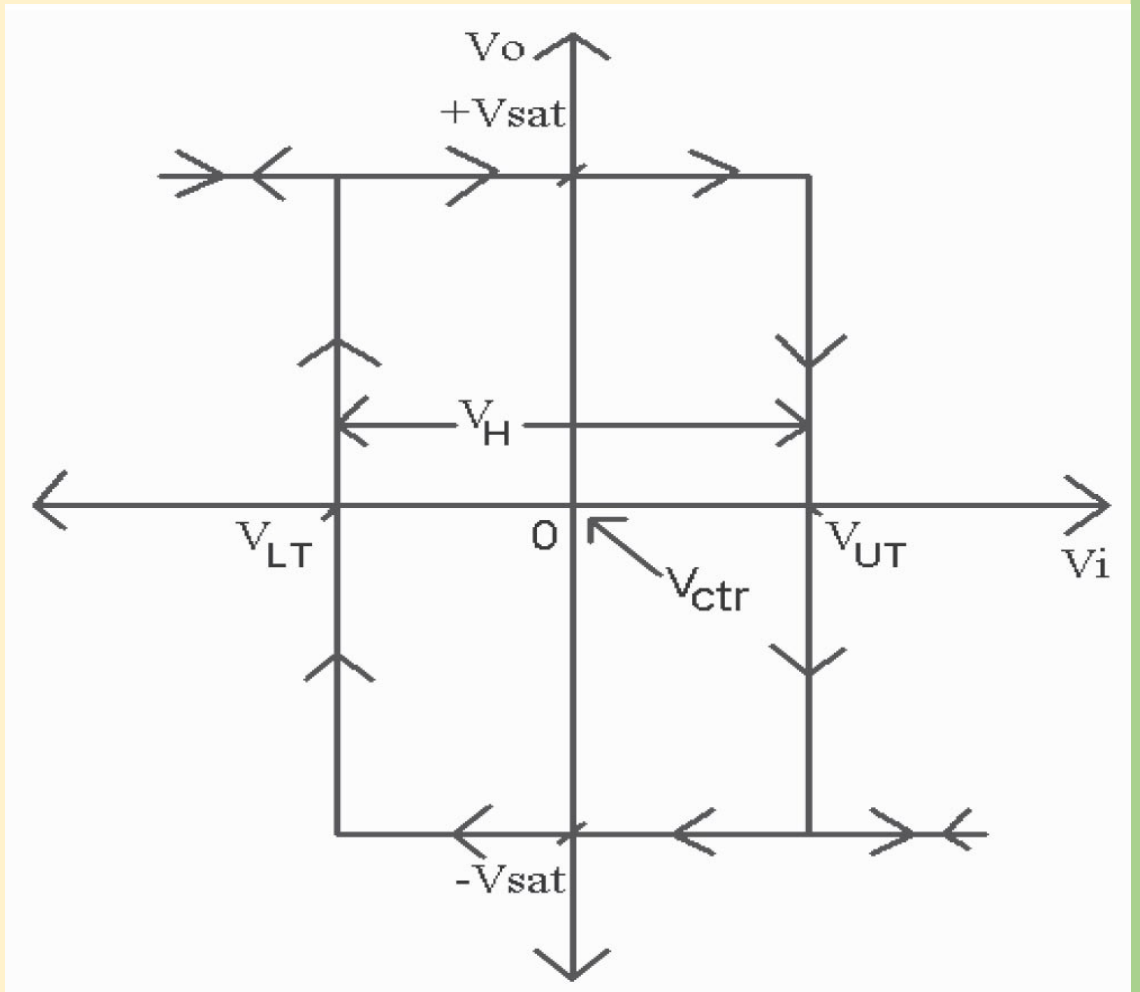
$$VUT = \frac{+Vsat}{1 + n}$$

$$VUT = \frac{+Vsat}{1+n}$$

$$VLT = \frac{-Vsat}{1+n}$$

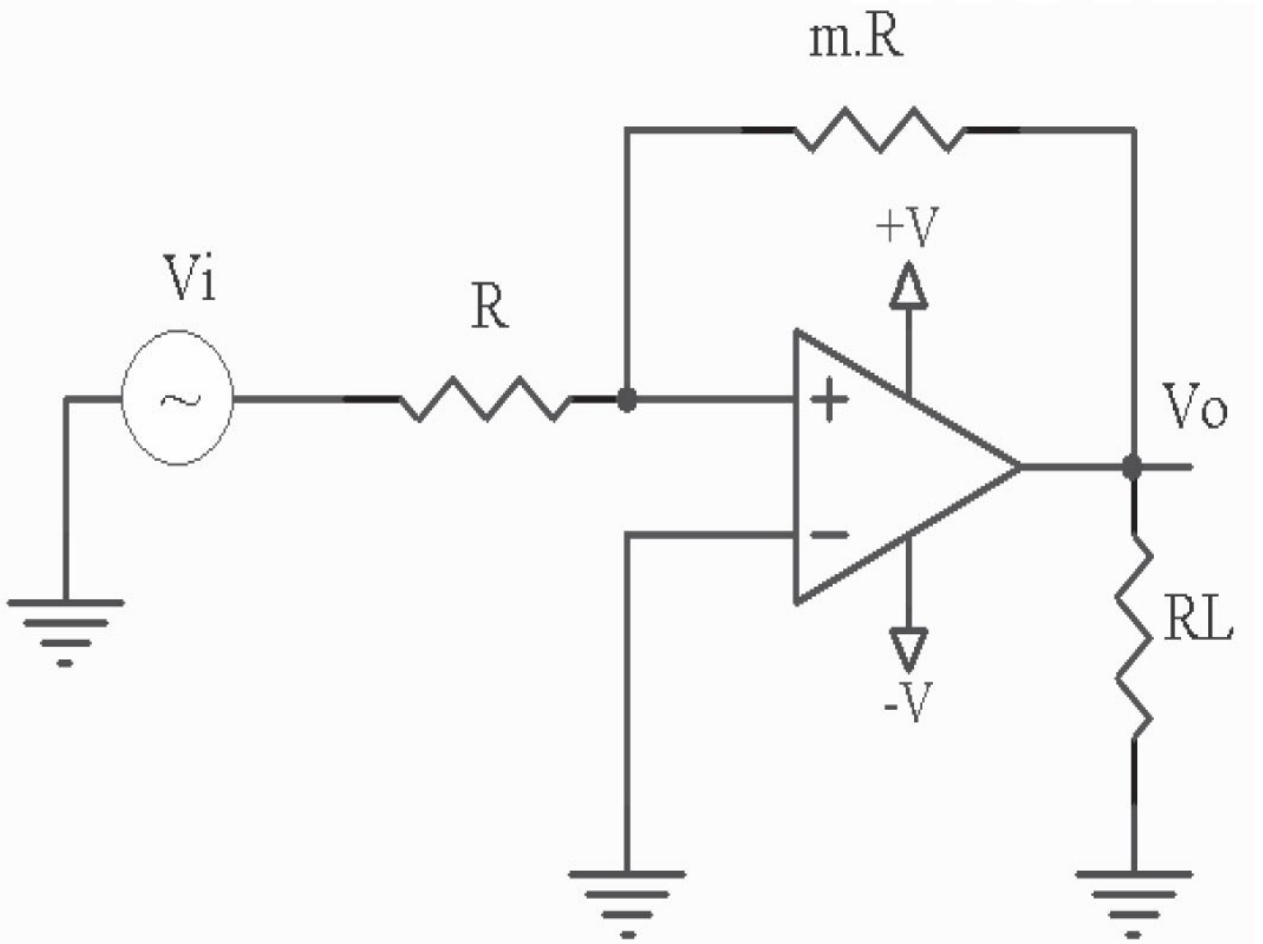
$$VH = VUT - VLT$$

$$Vctr = \frac{VUT + VLT}{2}$$

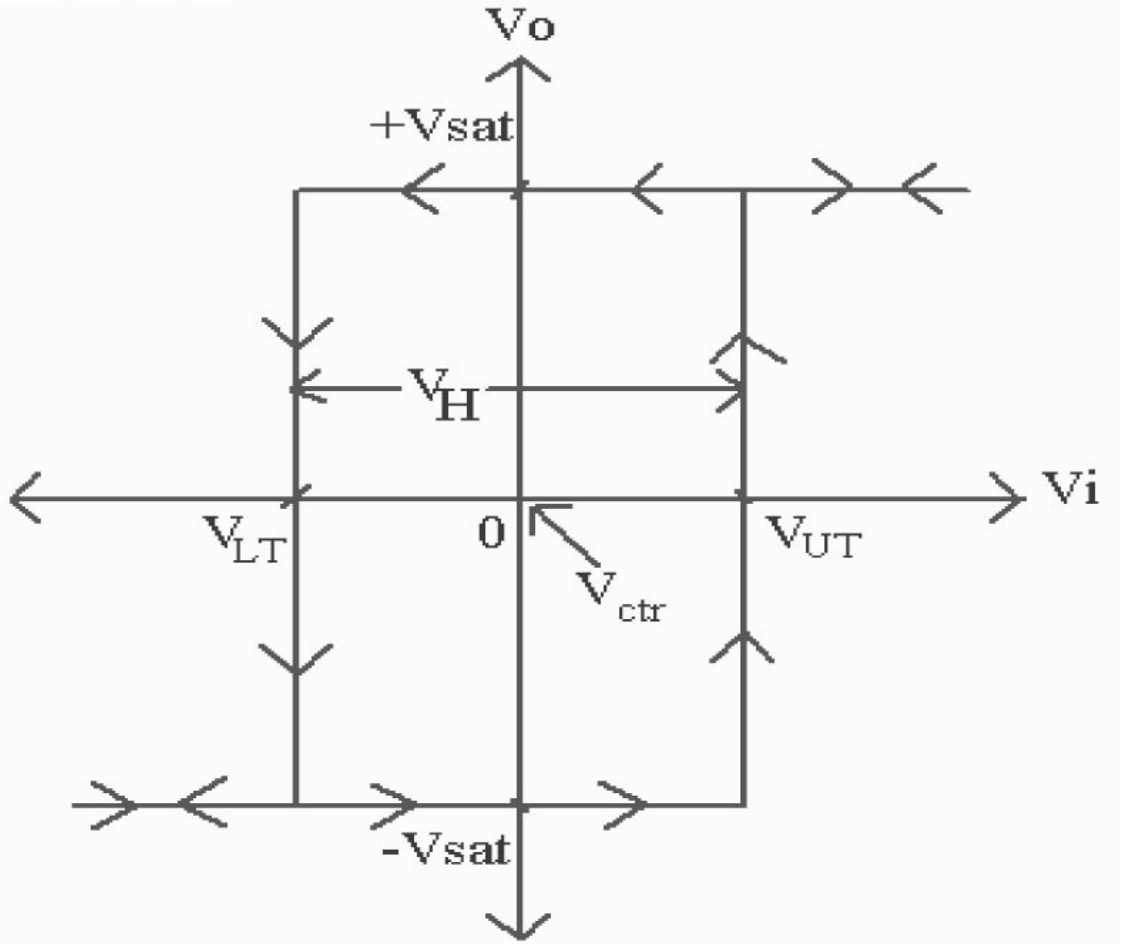


Karakteristik input-output dari IZCD dengan histerisis

NON INVERTING ZERO CROSSING DETECTOR WITH HYSTERESIS



Rangkaian NIZCD dengan histerisis

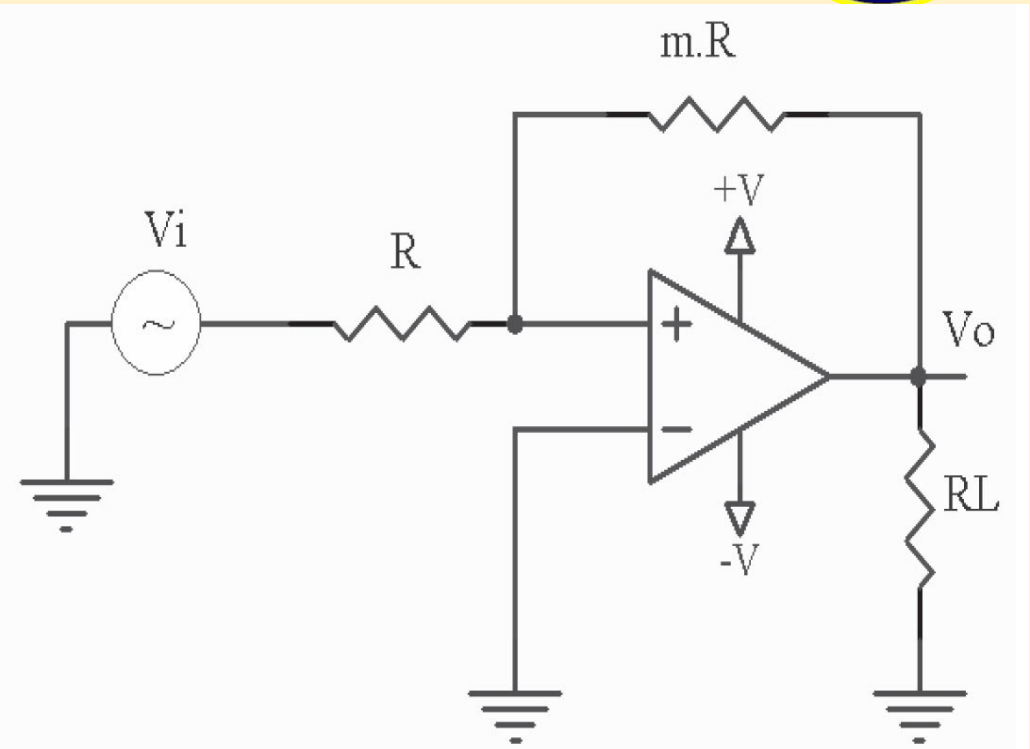


Karakteristik input-output NIZCD dengan histerisis

$$VIN = -\frac{R}{m.R}.(Vout)$$

$$VIN = -\frac{Vout}{\square}$$

$$VLT = -\frac{+Vsat}{\square}$$



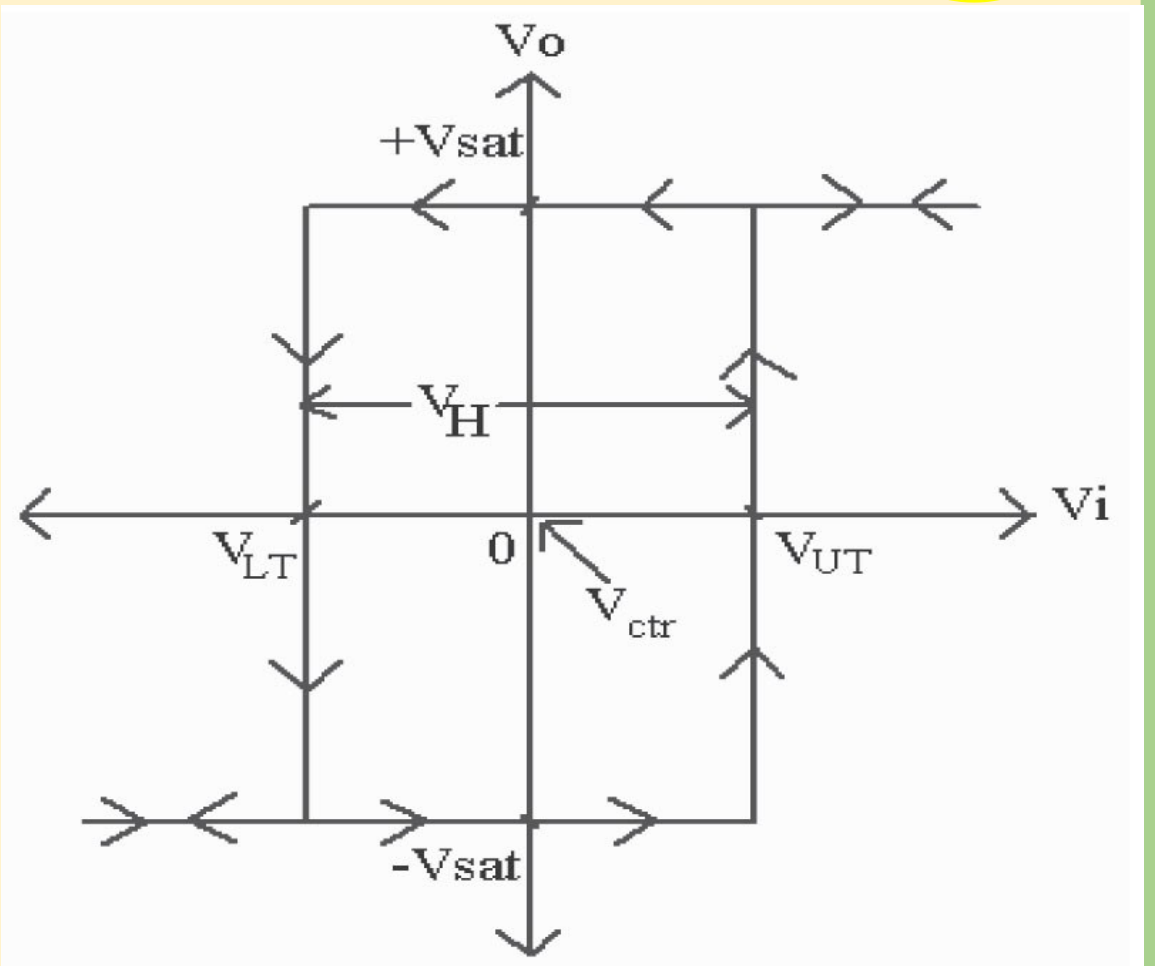
$$VUT = -\frac{-Vsat}{\square}$$

$$VUT = -\frac{-Vsat}{m}$$

$$VLT = -\frac{+Vsat}{m}$$

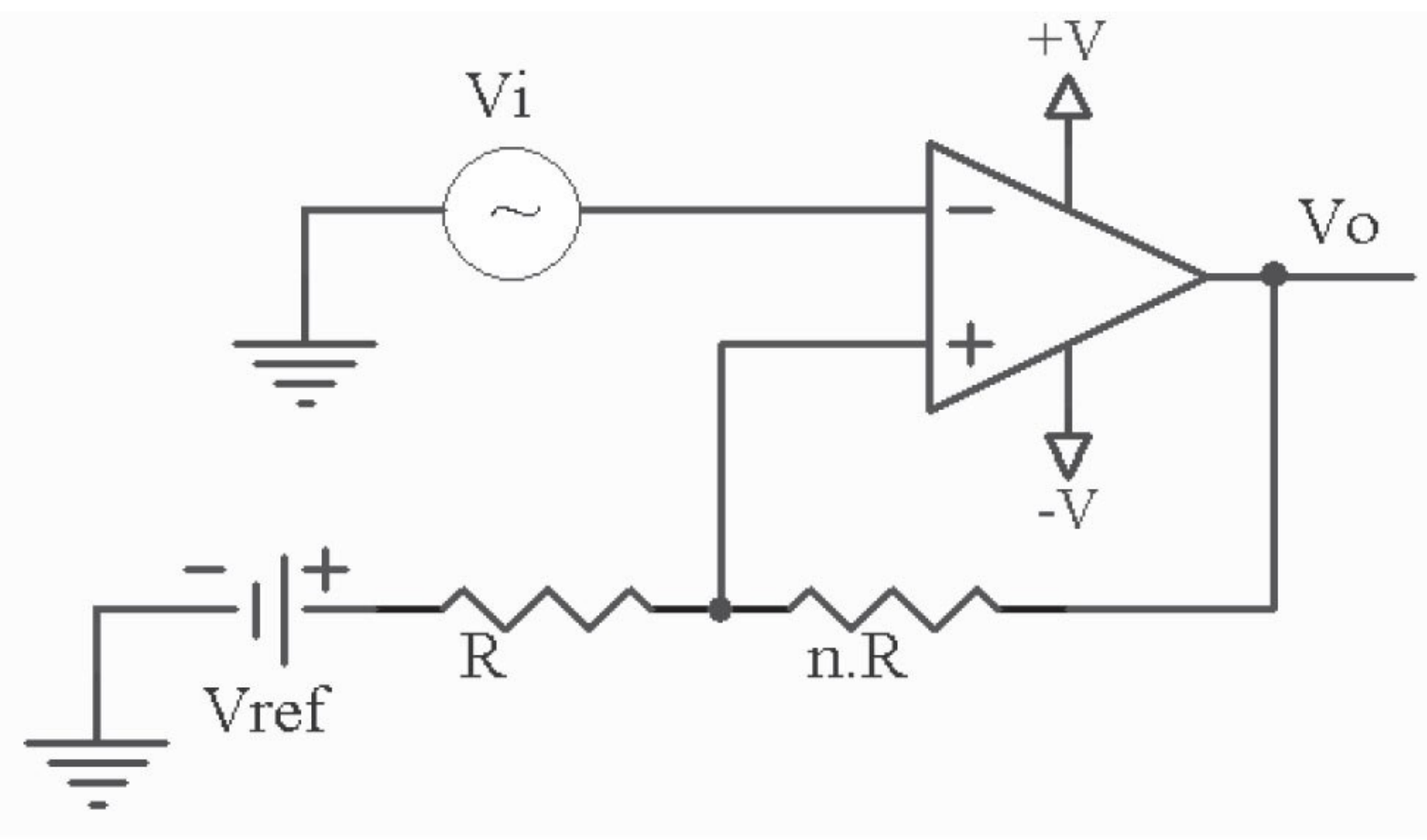
$$VH = VUT - VLT$$

$$Vctr = \frac{VUT + VLT}{2}$$



Karakteristik input-output NIZCD dengan histerisis

INVERTING VOLTAGE LEVEL DETECTOR WITH HYSTERESIS



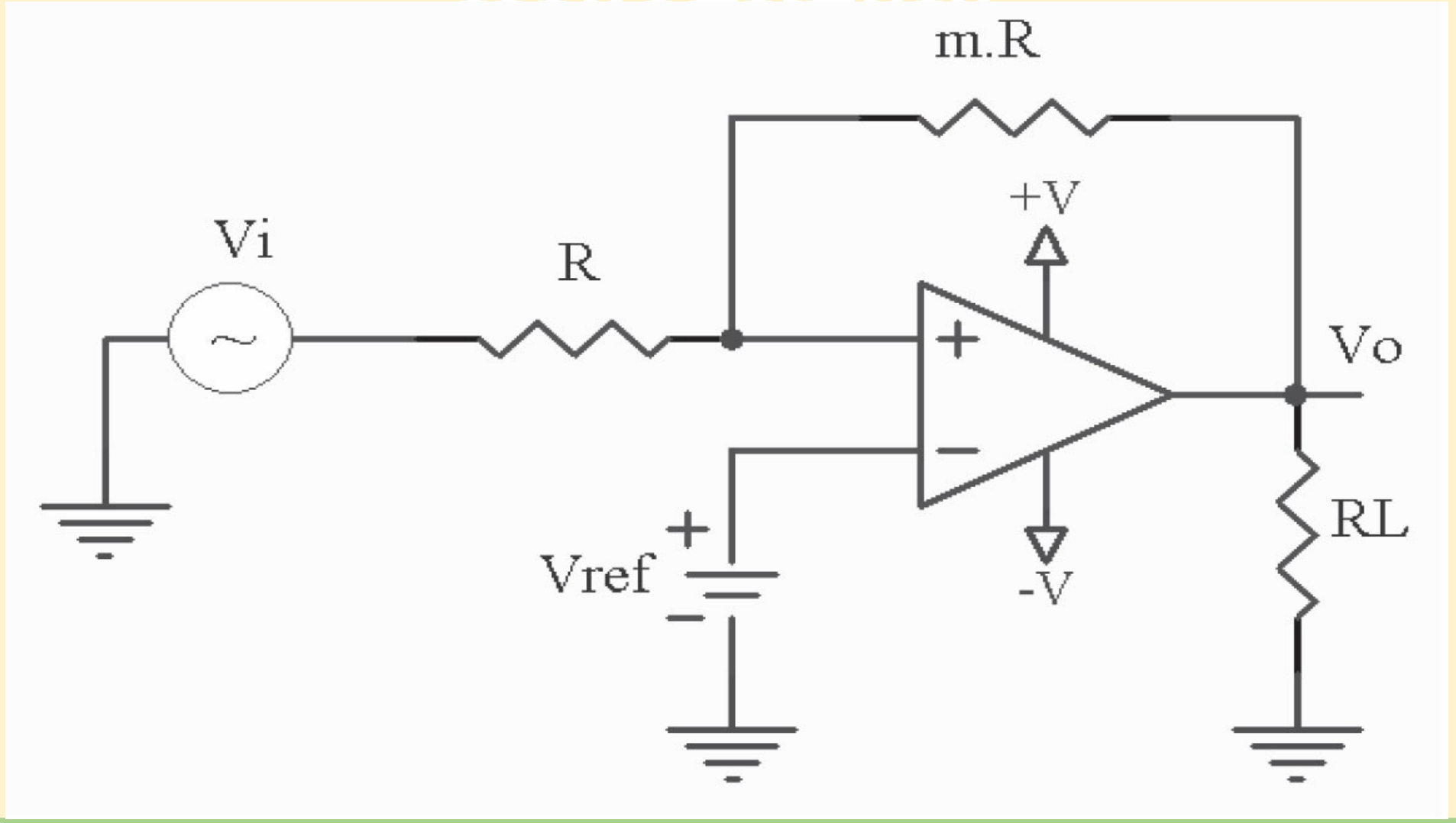
$$V_{UT} = \frac{n.R}{R+n.R}(Vref) + \frac{R}{R+n.R}(+Vsat) = \frac{n}{1+n}(Vref) + \frac{+Vsat}{1+n}$$

$$V_{LT} = \frac{n.R}{R+n.R}(Vref) + \frac{R}{R+n.R}(-Vsat) = \frac{n}{1+n}(Vref) + \frac{-Vsat}{1+n}$$

$$V_H = V_{UT} - V_{LT} = \frac{(+Vsat) - (-Vsat)}{1+n}$$

$$V_{ctr} = \frac{V_{UT} + V_{LT}}{2} = \frac{n}{1+n}.V_{ref}$$

NON INVERTING VOLTAGE LEVEL DETECTOR WITH HYSTERESIS



$$V_{UT} = \left(1 + \frac{1}{m}\right)(Vref) - \frac{-Vsat}{m}$$

$$V_{LT} = \left(1 + \frac{1}{m}\right)(Vref) - \frac{+Vsat}{m}$$

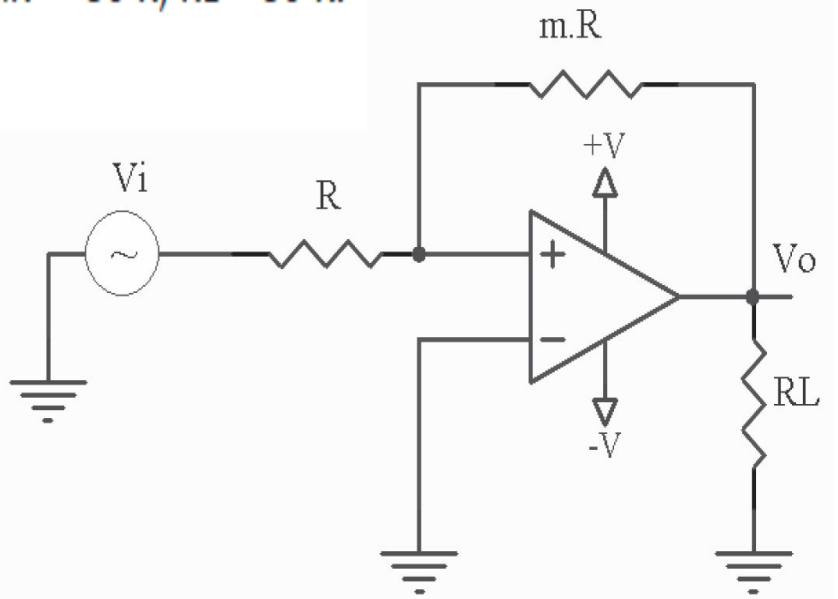
$$V_H = V_{UT} - V_{LT} = \frac{(+Vsat) - (-Vsat)}{m} = \frac{2.(+Vsat)}{m}$$

$$V_{ctr} = \frac{V_{UT} + V_{LT}}{2} = \left(1 + \frac{1}{m}\right).(Vref)$$

Soal 1

diketahui ± V = ± 15 volt, ± Vsat = ± 13 volt, R = 10 K, mR = 50 K, RL = 50 K.

Hitunglah V_{LT} dan V_{UT}, V_H, V_{ctr} dan gambarkan karakteristik *input-output*!



Penyelesaian:

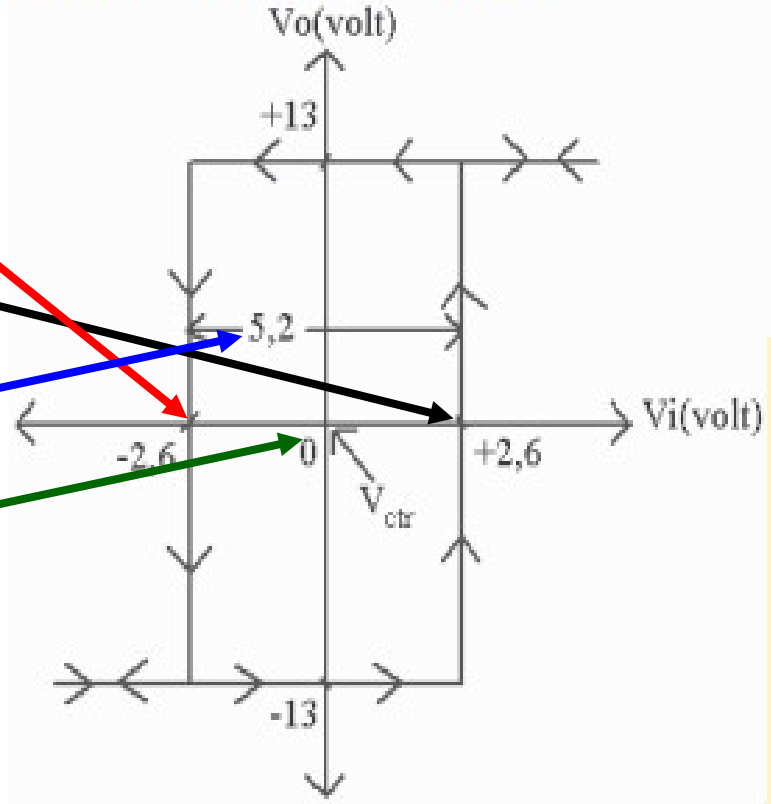
$$V_{LT} = -\frac{+Vsat}{m} = -\frac{13V}{5} = -2{,}6V$$

$$V_{UT} = -\frac{-Vsat}{m} = -\frac{-13V}{5} = +2{,}6V$$

$$V_H = V_{UT} - V_{LT} = 2{,}6 - (-2{,}6) = 5{,}2V$$

$$V_{ctr} = \frac{V_{UT} + V_{LT}}{2} = \frac{2{,}6V + (-2{,}6)}{2} = 0V$$

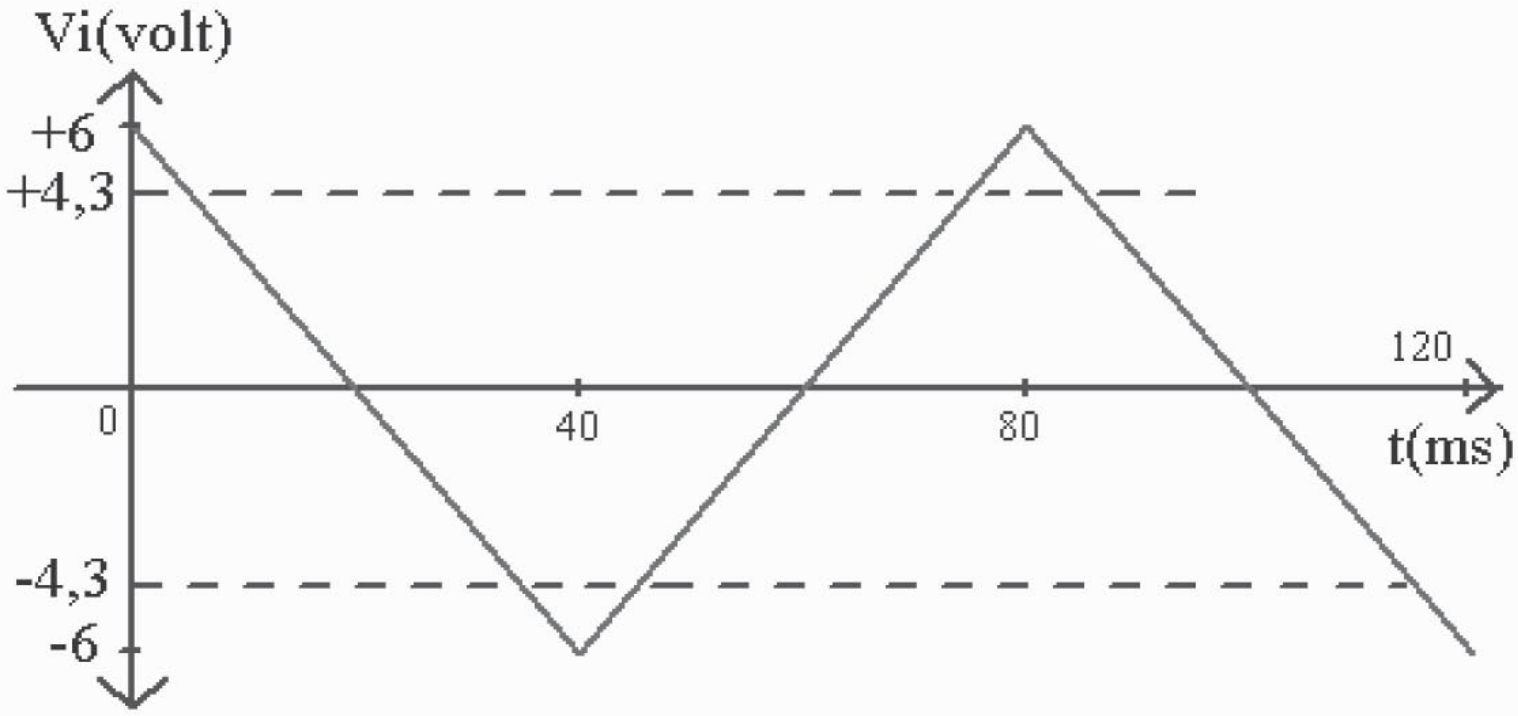
Karakteristik input-output:

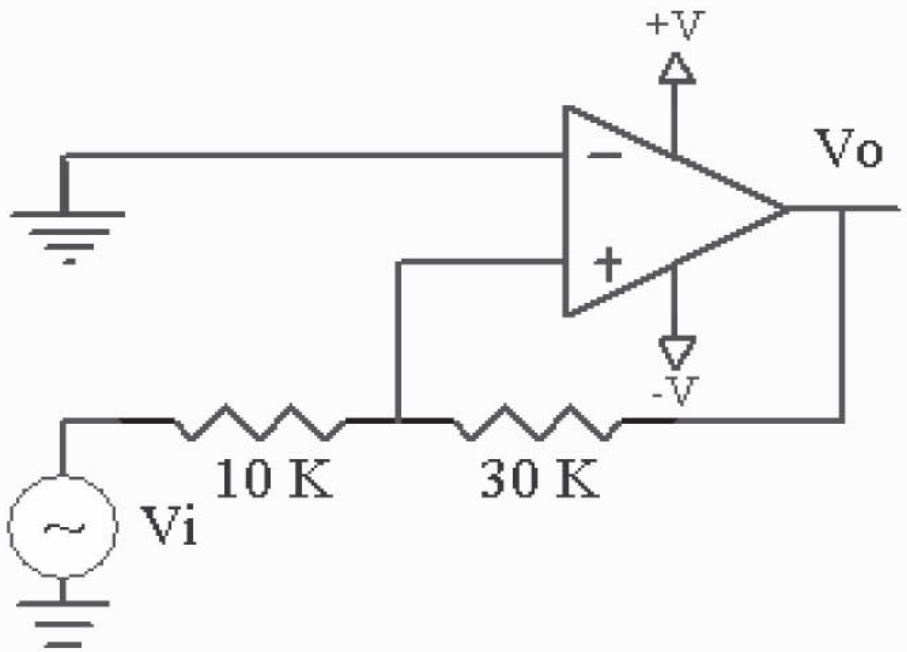


NIZCD dg Histeresis

Soal 2

Diketahui op-amp mempunyai ± V = ± 15 volt ± Vsat = ± 13 volt, R = 10 K, mR = 30 K, RL = 10 K. Hitunglah V_{LT} dan V_{UT}, V_H, V_{ctr}, t_H, t_L, *duty cycle* dan gambarkan tegangan Vo!





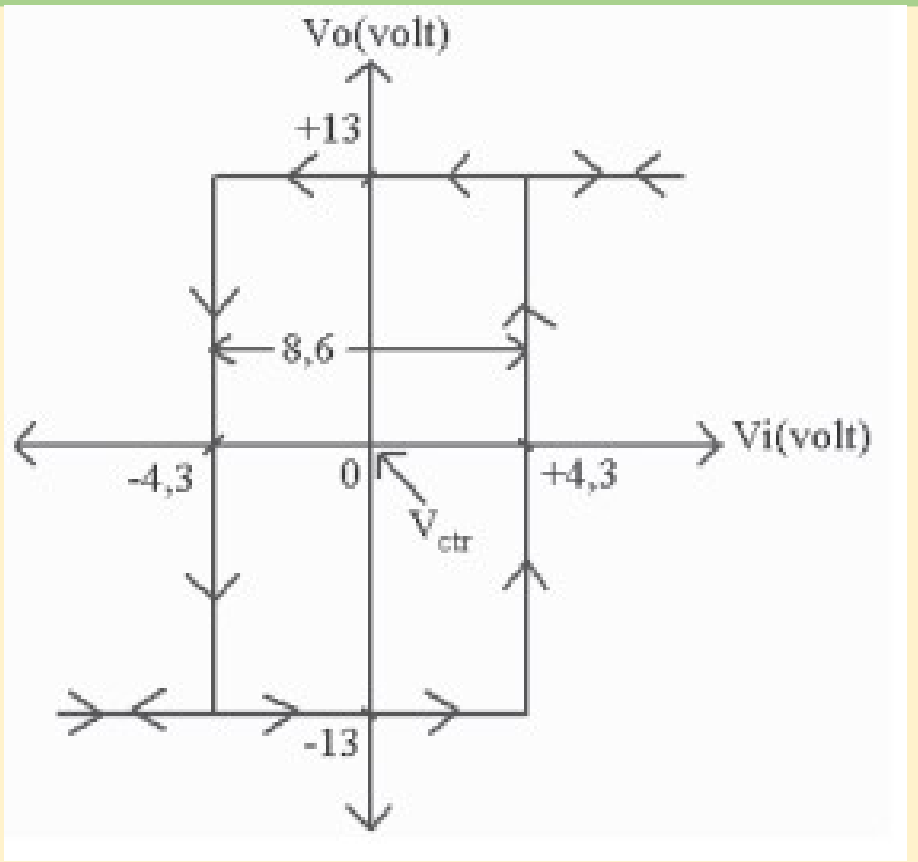
Penyelesaian:

$$V_{LT} = -\frac{+Vsat}{m} = -\frac{13V}{3} = -4{,}3V$$

$$V_{UT} = -\frac{-Vsat}{m} = -\frac{-13V}{3} = +4{,}3V$$

$$V_H = V_{UT} - V_{LT} = 4{,}3 - (-4{,}3) = 8{,}6V$$

$$V_{ctr} = \frac{V_{UT} + V_{LT}}{2} = \frac{4{,}3V + (-4{,}3V)}{2} = 0V$$



Untuk waktu: $0 < t < 40$: $Vi(t) = \frac{-12}{40}t + 6$

Pada saat t = t1, Vi(t) = −4,3 volt

Maka $-4{,}3 = \frac{-12}{40}t1 + 6$

$\frac{12}{40}t1 = 6 + 4{,}3$

$t1 = \frac{40}{12}.(10{,}3) = 34{,}3ms$

Untuk waktu: $40 < t < 80$: $Vi(t) = \frac{12V}{40}t + c$

Pada t = 40, Vi(t) = −6 volt

Maka $-6 = \frac{12}{40}.(40) + c$

Dan $Vi(t) = \frac{12}{40}.t - 18$

Pada saat t = t2, Vi(t) = 4,3 volt

Maka: $4{,}3 = \frac{12}{40}.t2 - 18$

$t2 = (4{,}3 + 18)\frac{40}{12} = 22{,}3.\frac{40}{12} = 74{,}3ms$

Untuk waktu: $80 < t < 120$: $Vi(t) = -\frac{12}{40}.t + c$

Pada t = 80, Vi(t) = 6 volt

Maka: $6 = -\frac{12}{40}.(80) + c$

$c = 6 + 24 = 30$

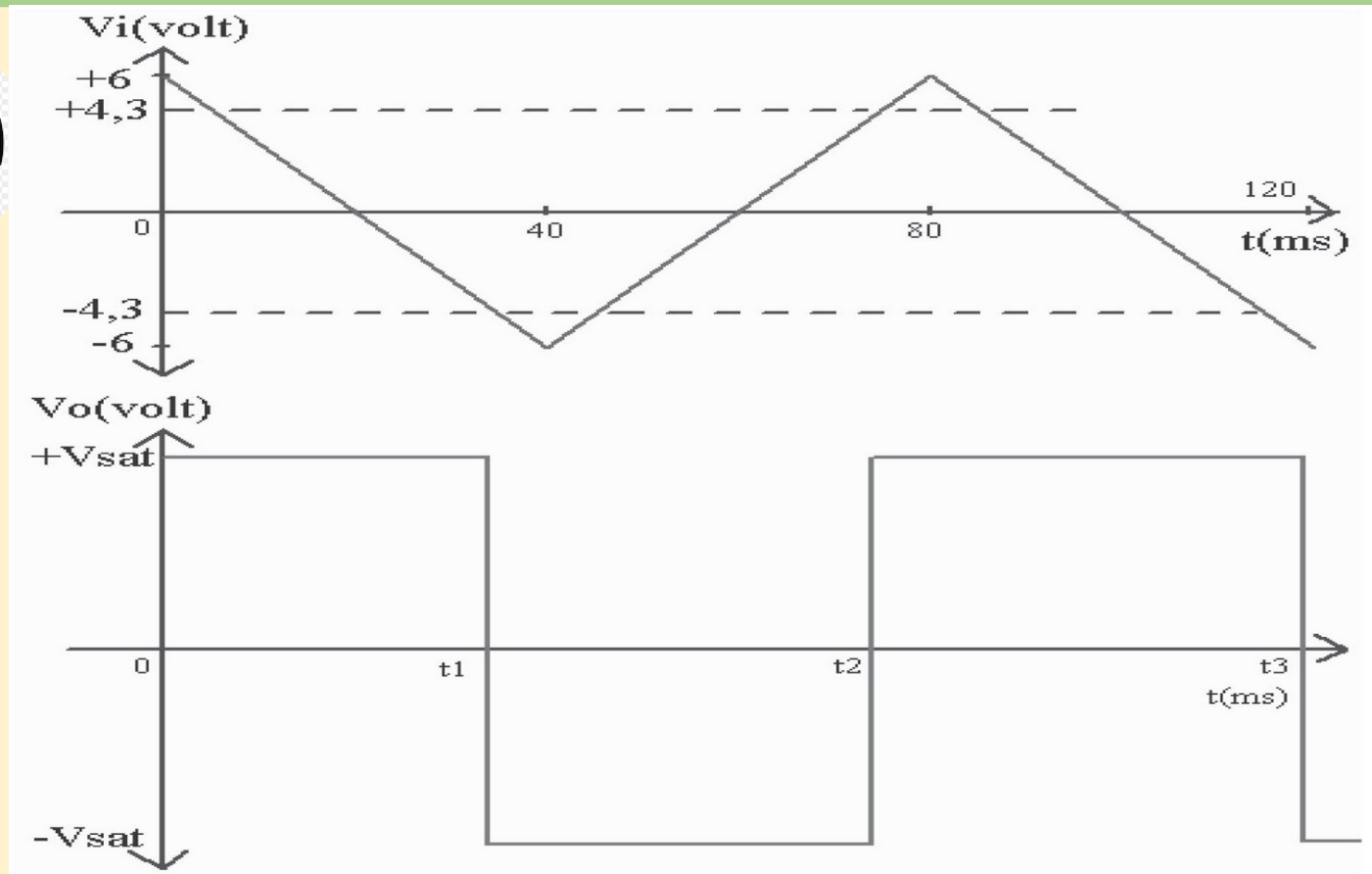
Dan $Vi(t) = -\frac{12}{40}.t + 30$

Pada saat t = t3, Vi(t) = −4,3 volt

Maka: $-4{,}3 = -\frac{12}{40}.t3 + 30$

$\frac{12}{40}.t3 = 30 + 4{,}3$

$t3 = 34{,}3.\frac{40}{12} = 114{,}3ms$



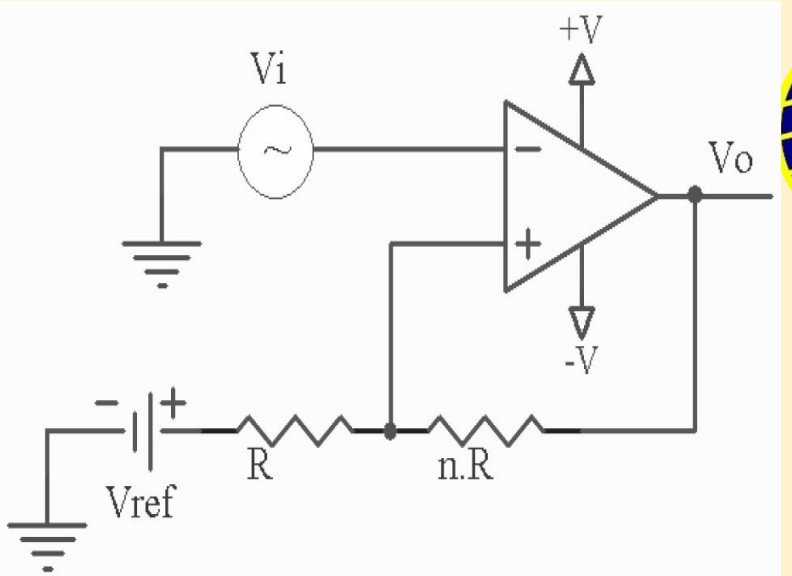
Maka $tH = t3 - t2 = 114,3 - 74,3 = 40$ ms

$tL = t2 - t1 = 74,3 - 34,3 = 40$ ms

$T = tH + tL = 40 + 40 = 80$ ms

$$Dutycycle\ (DC) = \frac{tH}{T} \times 100\% = \frac{40}{80} \times 100\% = 50\%$$

Soal 3



Diketahui op-amp dengan $\pm V = \pm 15$ volt $\pm Vsat = \pm 14$ volt.

R = 10 K, nR = 40 K, Vref = 2 volt.

a. Hitunglah V_{LT} dan V_{UT}, V_H, V_{ctr}.

b. Gambarkan karakteristik input-output.

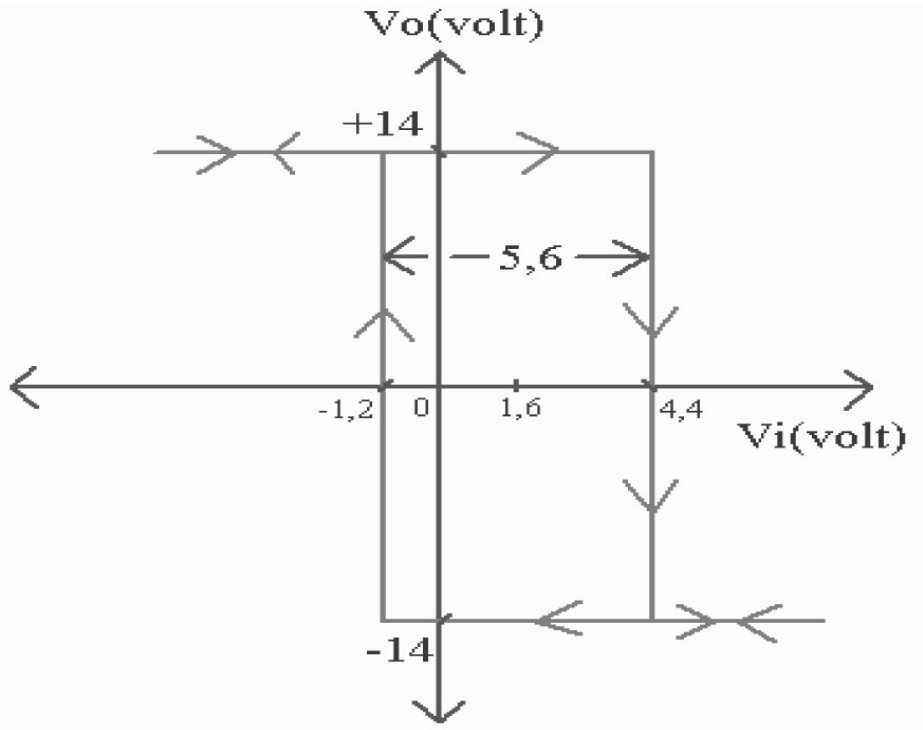
Penyelesaian:

$$V_{LT} = \frac{n}{1+n}(V_{ref}) + \frac{-Vsat}{1+n} = \frac{4}{1+4}.(2) + \frac{-14}{1+4} = 1{,}6 - 2{,}8 = -1{,}2\ V$$

$$V_{UT} = \frac{n}{1+n}(V_{ref}) + \frac{+Vsat}{1+n} = \frac{4}{1+4}.(2) + \frac{14}{1+4} = 1{,}6 + 2{,}8 = 4{,}4\ V$$

$$V_H = V_{UT} - V_{LT} = 4{,}4 - (-1{,}2) = 5{,}6\ volt$$

$$V_{ctr} = \frac{V_{UT} + V_{LT}}{2} = \frac{4{,}4 + (-1{,}2)}{2} = 1{,}6\ volt$$



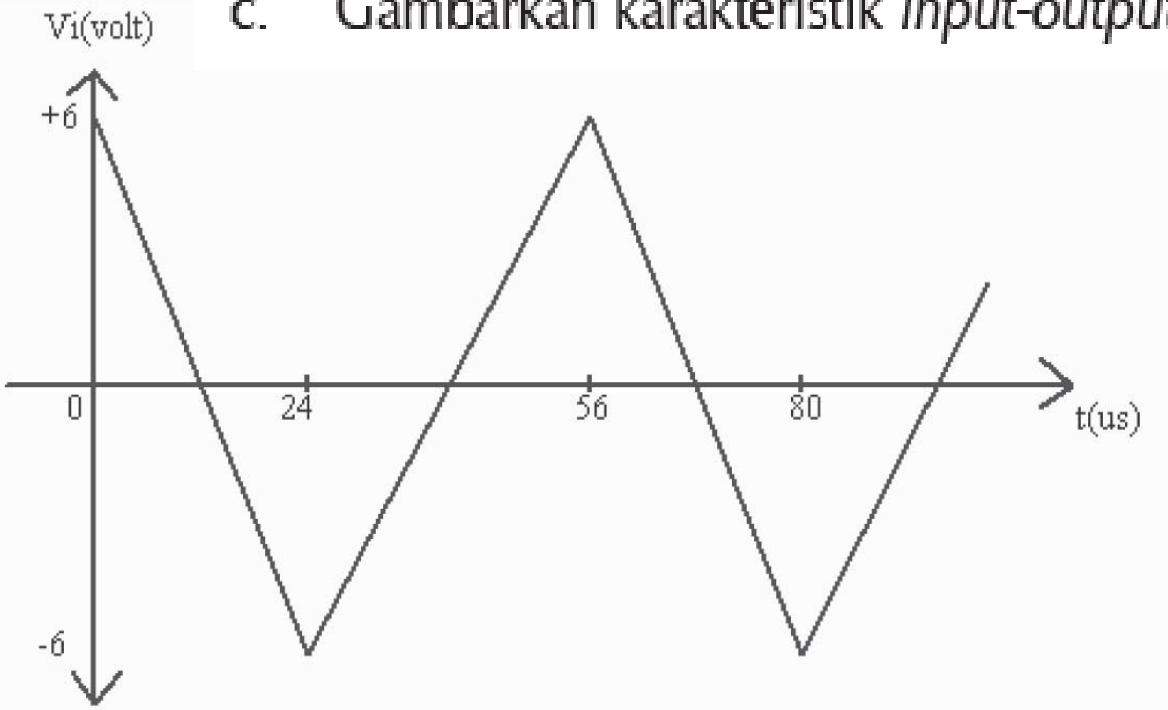
Soal 4

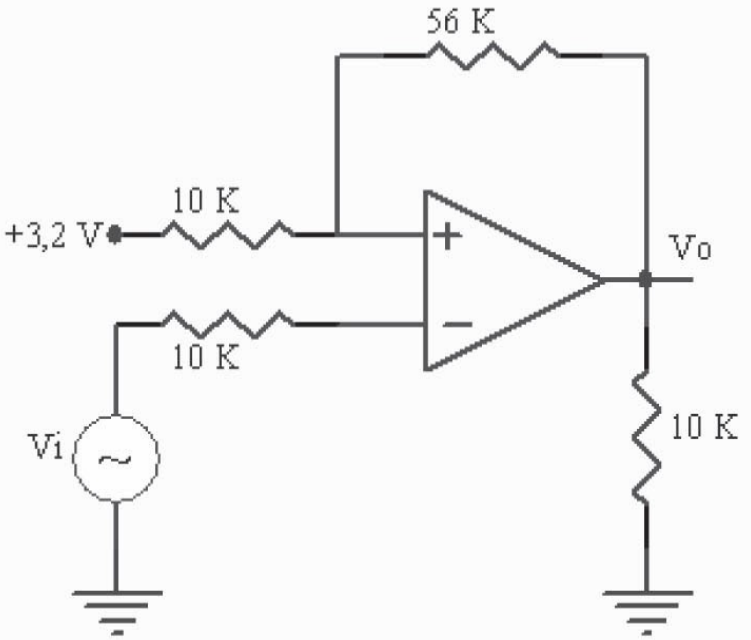
Diketahui op-amp dengan ± V = ± 15 volt ± Vsat = ± 13 volt.

a. Hitunglah V_{LT} dan V_{UT}, V_H, V_{ctr}, t_H, t_L *duty cycle*.

b. Gambarkan tegangan *output* Vo.

c. Gambarkan karakteristik *input-output*.





Penyelesaian:

$$n = \frac{56}{10} = 5{,}6 \text{ dan } Vref = 3{,}2 \text{ volt}$$

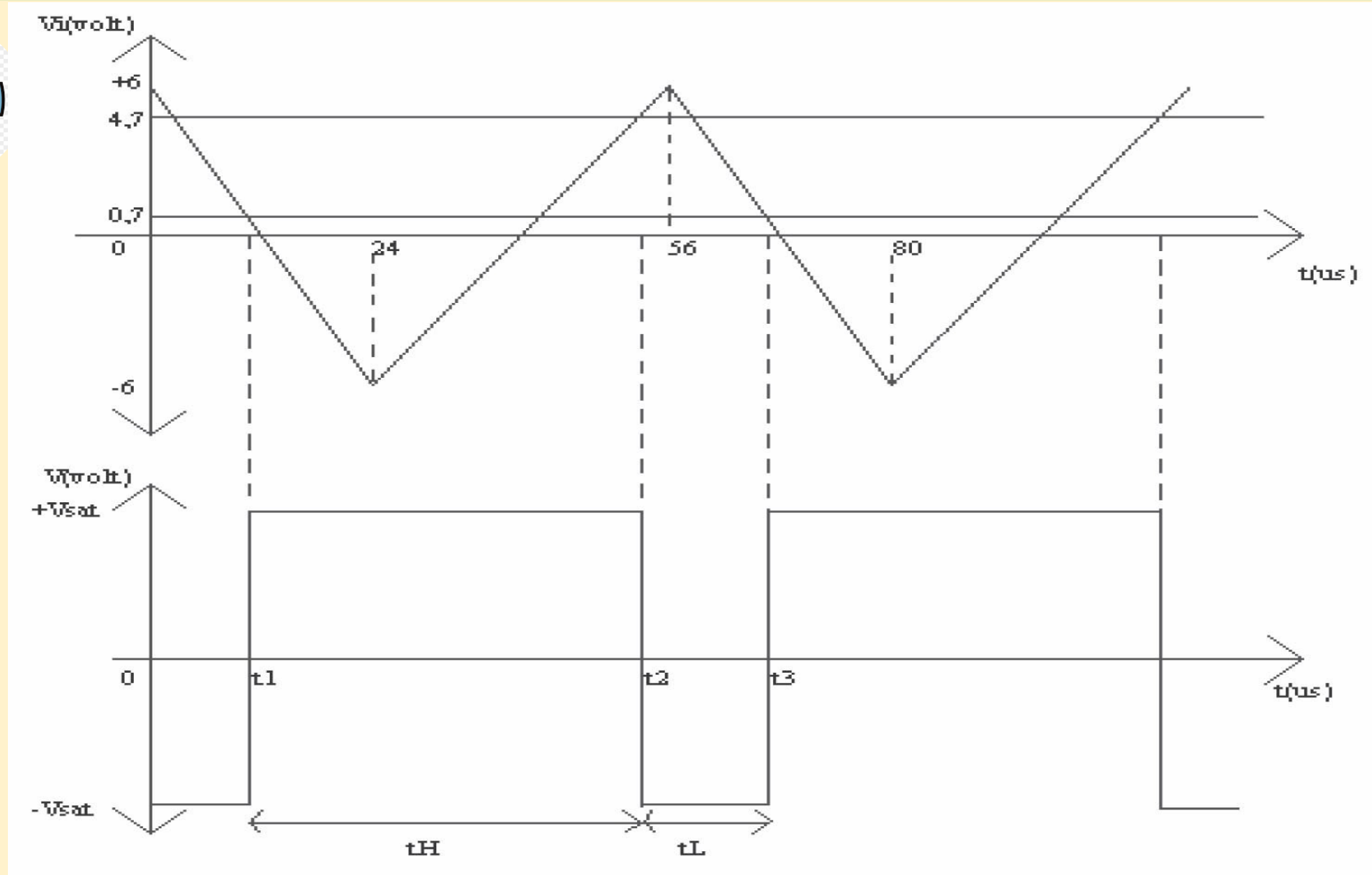
Rangkaian *inverting voltage level detector* dengan histerisis, dengan Vref = positif maka *duty cycle*-nya adalah lebih dari 50 %.

$$V_{UT} = \frac{n}{n+1}(V_{ref}) + \frac{+Vsat}{n+1} = \frac{5{,}6}{5{,}6+1}.(3{,}2) + \frac{13}{5{,}6+1} = 2{,}7 + 2 = 4{,}7 \text{ volt}$$

$$V_{LT} = \frac{n}{n+1}(V_{ref}) + \frac{-Vsat}{n+1} = \frac{5{,}6}{5{,}6+1}.(3{,}2) + \frac{-13}{5{,}6+1} = 2{,}7 - 2 = 0{,}7 \text{ volt}$$

$$V_H = V_{UT} - V_{LT} = \frac{(+Vsat)-(-Vsat)}{1+n} = \frac{13 + (-13)}{1 + 5{,}6} = 4 \text{ volt}$$

$$V_{ctr} = \frac{V_{UT} + V_{LT}}{2} = \frac{n}{1+n}.(V_{ref}) = \frac{5{,}6}{1 + 5{,}6}(3{,}2) = 2{,}7 \text{ volt}$$


Vi(volt)
+6
4,7
0,7
0
24
56
80
t(us)
-6
V(volt)
+Vsat
0
t1
t2
t3
t(us)
-Vsat
tH
tL

Untuk waktu: $0 < t < 24$: $Vi(t) = \frac{-12}{24}t + 6$

$Vi(t) = -0,5.t + 6$

Pada saat $t = t1$, $Vi(t) = 0,7$ volt

Maka $0,7 = -0,5.t1 + 6$

$0,5.t1 = 6 - 0,7$

$t1 = \frac{5,3}{0,5} = 10,6\mu s$

Untuk waktu: $24 < t < 56$: $Vi(t) = \frac{12}{32}t + c$

Pada saat $t = 24$, $Vi(t) = -6$ volt

Maka: $-6 = \frac{12}{32}.(24) + c$

$C = -15$

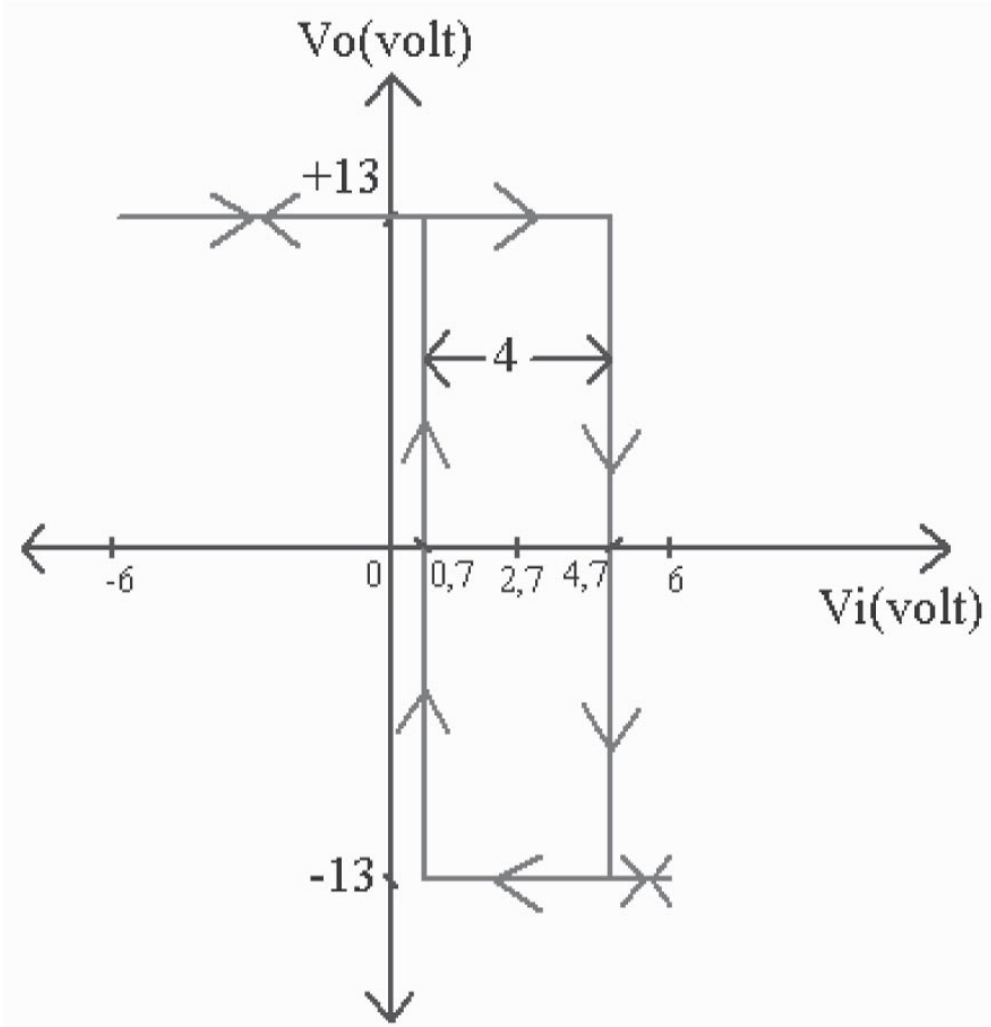
Dan $Vi(t) = \frac{3}{8}t - 15$

Pada saat $t = t2$, $Vi(t) = 4,7$ volt

Maka: $4,7 = \frac{3}{8}.t2 - 15$

$\frac{3}{8}.t2 = 4,7 + 15$

$t2 = 52,53\ \mu s$



Untuk waktu: $56 < t < 80$: $Vi(t) = -0{,}5t + c$

Pada saat t = 56, Vi(t) = 6 volt

Maka: $6 = -0{,}5(56) + c$

C = 34

Dan $Vi(t) = -0{,}5.t + 34$

Pada saat t = t3, Vi(t) = 0,7 volt

Maka: $0{,}7 = -0{,}5.t3 + 34$

$0{,}5.t3 = 34 - 0{,}7$

$t3 = 66{,}6\ \mu s$

Maka

tH = t2 - t1 = 52,53 - 10,6 = 41,93 us

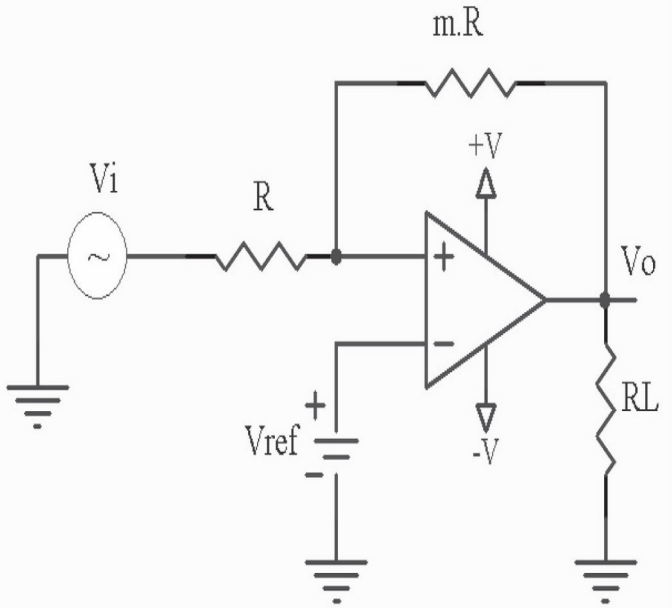
tL = t3 – t2 = 66,6 – 52,53 = 14,07 us

T = tH + tL = 41,93 + 14,07 = 56 us

Untuk waktu: $24 < t < 56$

$$Dutycycle(DC) = \frac{41{,}9}{56} \times 100\% = 74{,}88\%$$

Soal 5



Diketahui op-amp dengan ± V = ± 15 volt; ± Vsat = ± 14 volt.

R = 10 K, mR = 40 K, Vref = 2 volt.

a. Hitunglah V_{LT} dan V_{UT}, V_H, V_{ctr}!

b. Gambarkan karakteristik *input-output*!

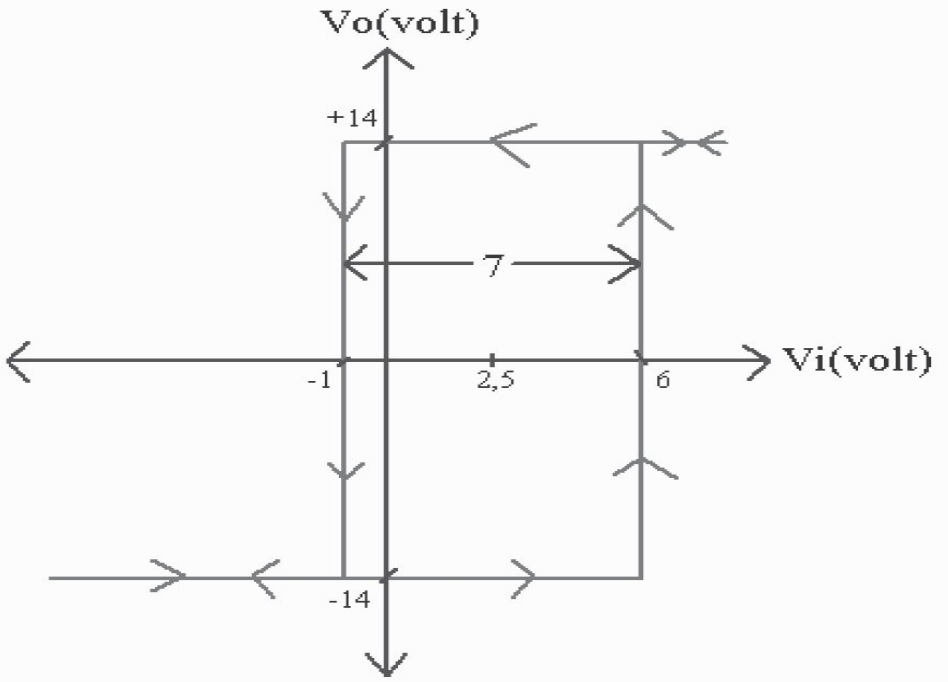
Penyelesaian:

$$V_{LT} = \left(1 + \frac{1}{m}\right)(Vref) - \frac{+Vsat}{m} = \left(1 + \frac{1}{4}\right)(2) - \frac{+14}{4} = 2{,}5 - 3{,}5 = -1 \text{ volt}$$

$$V_{UT} = \left(1 + \frac{1}{m}\right)(Vref) - \frac{-Vsat}{m} = \left(1 + \frac{1}{4}\right)(2) - \frac{-14}{4} = 2{,}5 + 3{,}5 = 6 \text{ volt}$$

$$V_H = V_{UT} - V_{LT} = 6 - (-1) = 7 \text{ volt}$$

$$V_{ctr} = \frac{V_{UT} + V_{LT}}{2} = \frac{6 + (-1)}{2} = 2{,}5 \text{ volt}$$



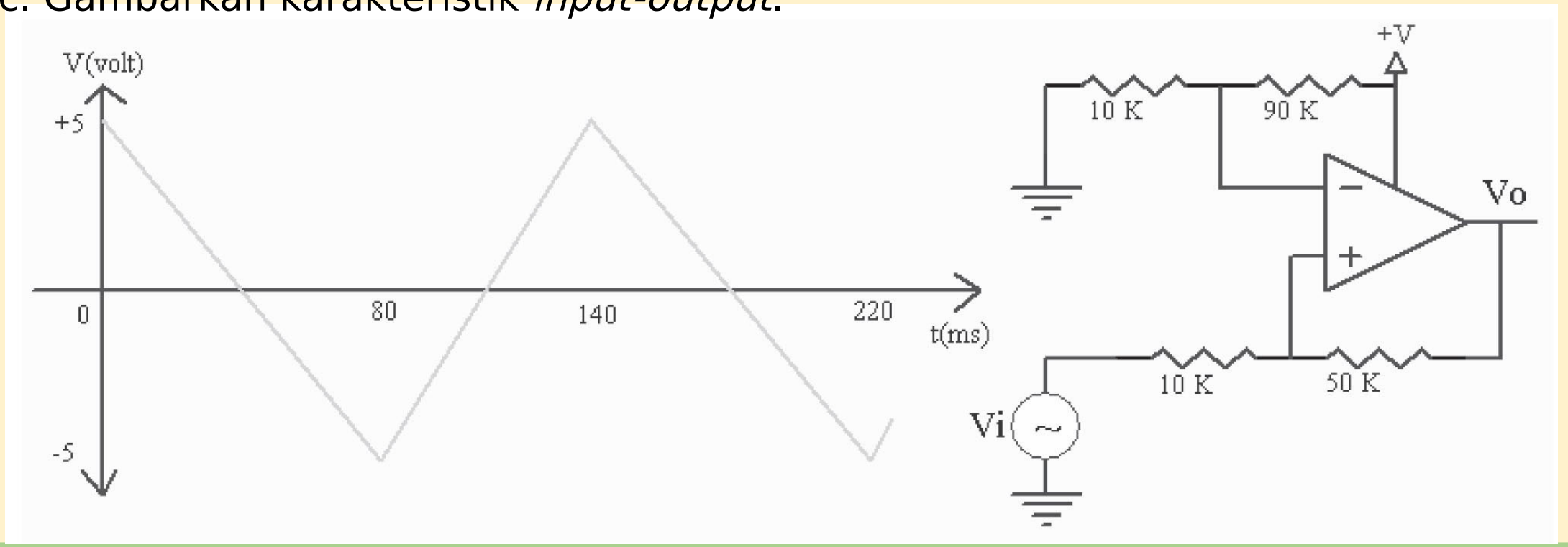
Soal 6

Diketahui op-amp dengan ± V = ± 15 volt; ± Vsat = ± 13 volt.

a. Hitunglah V_{LT} dan V_{UT}, V_H, V_{ctr}, t_H, t_L *duty cycle*!

b. Gambarkan tegangan output Vo!

c. Gambarkan karakteristik *input-output*.



Penyelesaian:

$$m = \frac{mR}{m} = \frac{50}{10} = 5 \text{ dan}$$

$$Vref = \frac{10K}{10K + 90K}(+15) = 1{,}5 \text{ volt}$$

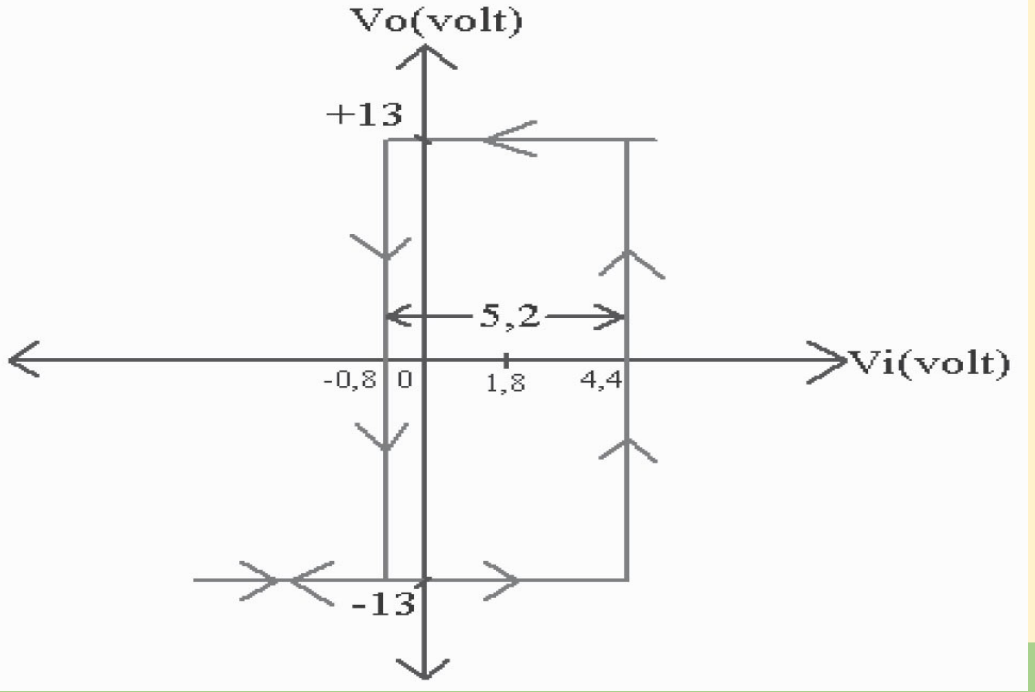
Rangkaian *noninverting voltage level detector* dengan histerisis, dengan Vref = positif maka *duty cycle*-nya adalah kurang dari 50 %.

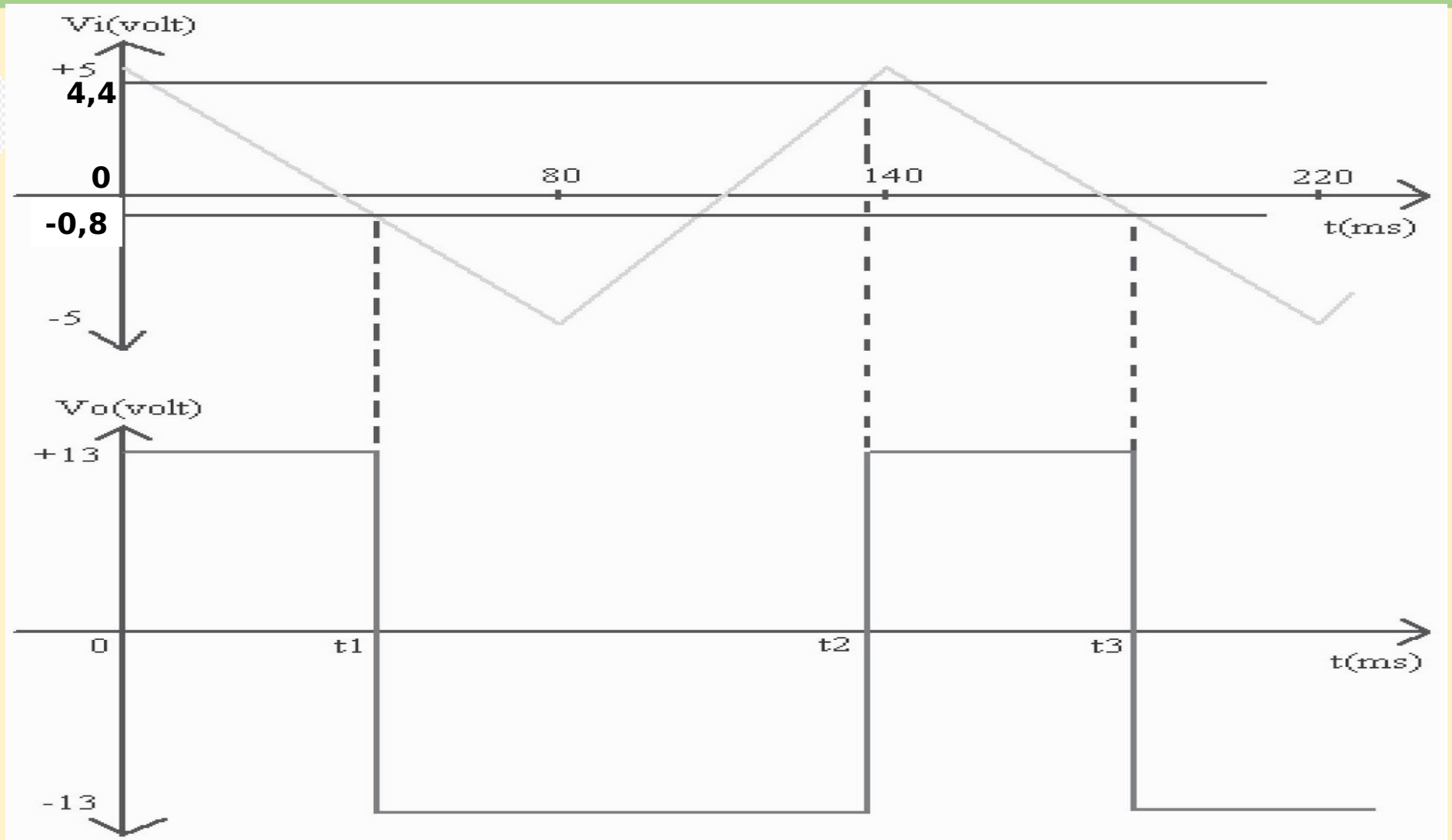
$$V_{LT} = \left(1 + \frac{1}{m}\right)(Vref) - \frac{+Vsat}{m} = \left(1 + \frac{1}{5}\right)(1{,}5) - \frac{+13}{5} = 1{,}8 - 2{,}6 = -0{,}8 \text{ volt}$$

$$V_{UT} = \left(1 + \frac{1}{m}\right)(Vref) - \frac{-Vsat}{m} = \left(1 + \frac{1}{5}\right)(1{,}5) - \frac{-13}{5} = 1{,}8 + 2{,}6 = 4{,}4 \text{ volt}$$

$$V_H = V_{UT} - V_{LT} = 4{,}4 - (-0{,}8) = 5{,}2 \text{ volt}$$

$$V_{ctr} = \frac{V_{UT} + V_{LT}}{2} = \frac{4{,}4 + (-0{,}8)}{2} = 2{,}2 - 0{,}4 = 1{,}8 \text{ volt}$$




Vi(volt)
+5
4,4
0
-0,8
-5
80
140
220
t(ms)
Vo(volt)
+13
0
t1
t2
t3
t(ms)
-13

Untuk waktu: $0 < t < 80$: $Vi(t) = \frac{-10}{80}t + 5$

Pada saat t = t1, Vi(t) = −0,8 volt

Maka: $-0,8 = \frac{-10}{80}t1 + 5$

$\frac{1}{8}t1 = 5 + 0,8$

$t1 = 40 + 6,4 = 46,4ms$

Untuk waktu: $80 < t < 140$: $Vi(t) = \frac{10}{60}t + c$

Pada saat t = 80, Vi(t) = −5 volt

Maka: $-5 = \frac{1}{6}(80) + c$

$c = -5 - \frac{80}{6} = -5 - 13\frac{2}{6} = -18\frac{2}{6}$

Dan $Vi(t) = \frac{1}{6}t - 18\frac{2}{6}$

Pada saat t = t2, Vi(t) = 4,4 volt

Maka: $4,4 = \frac{-1}{6}t2 - 18\frac{2}{6}$

$\frac{1}{6}.t2 = 4,4 + 18\frac{2}{6}$

$t2 = 26,4 + 110 = 136,4ms$

Untuk waktu: $140 < t < 220$: $Vi(t) = -\frac{10}{80}.t + c$

Pada saat t = 140, Vi(t) = 5 volt

Maka: $5 = -\frac{1}{8}.(140) + c$

$c = 17\frac{4}{8} + 5 = 22,5$

Dan $Vi(t) = -\frac{1}{8}.t + 22,5$

Pada saat t = t3, Vi(t) = −0,8 volt

Maka: $-0,8 = -\frac{1}{8}.t3 - 22,5$

$\frac{1}{8}.t3 = 22,5 + 0,8 = 23,3$

$t3 = 186,4ms$

Maka: $t_H = t3 – t2 = 186,4 - 136,4 = 50$ ms

$t_L = t2 – t1 = 136,4 – 46,4 = 90$ ms

$T = t_H + t_L = 50 + 90 = 140$ ms

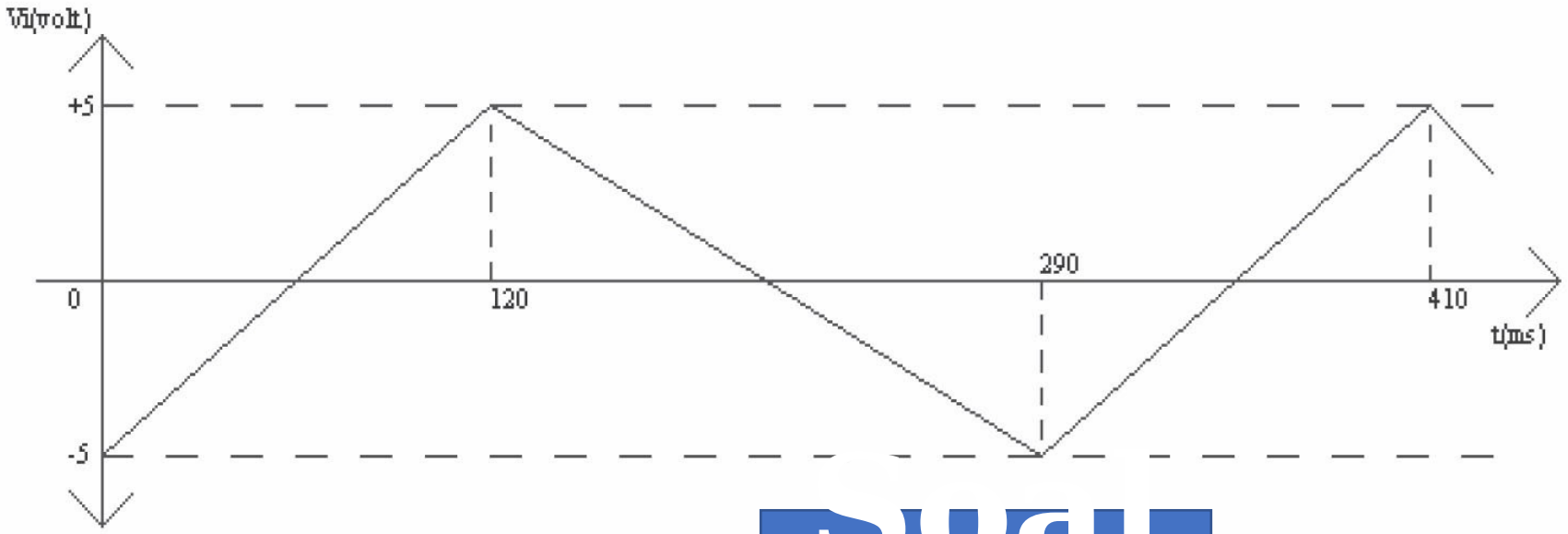
$$Dutycycle(DC) = \frac{50}{140} \times 100\% = 35,7\%$$

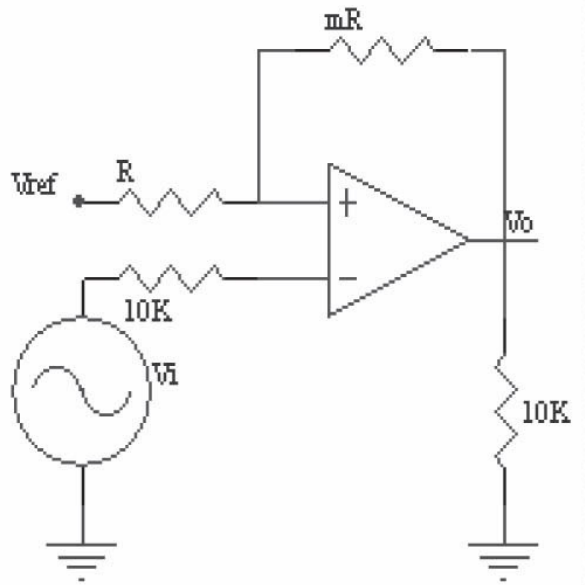
Diketahui op-amp dengan ± V = ± 15 volt; ± Vsat = ± 14 volt. Rencanakan rangkaian *voltage level detector* dengan histeresis agar didapat tegangan output dengan *duty cycle* = 30 %.

Penyelesaian:

Ada dua rangkaian *voltage level detector* yaitu IVLD dengan histeresis dan NIVLD dengan histeresis.

* Apabila jenis IVLD dengan histeresis dan *duty cycle* = 30 % maka Vref = negatif





Soal 7

$T = 290\ \text{ms}$

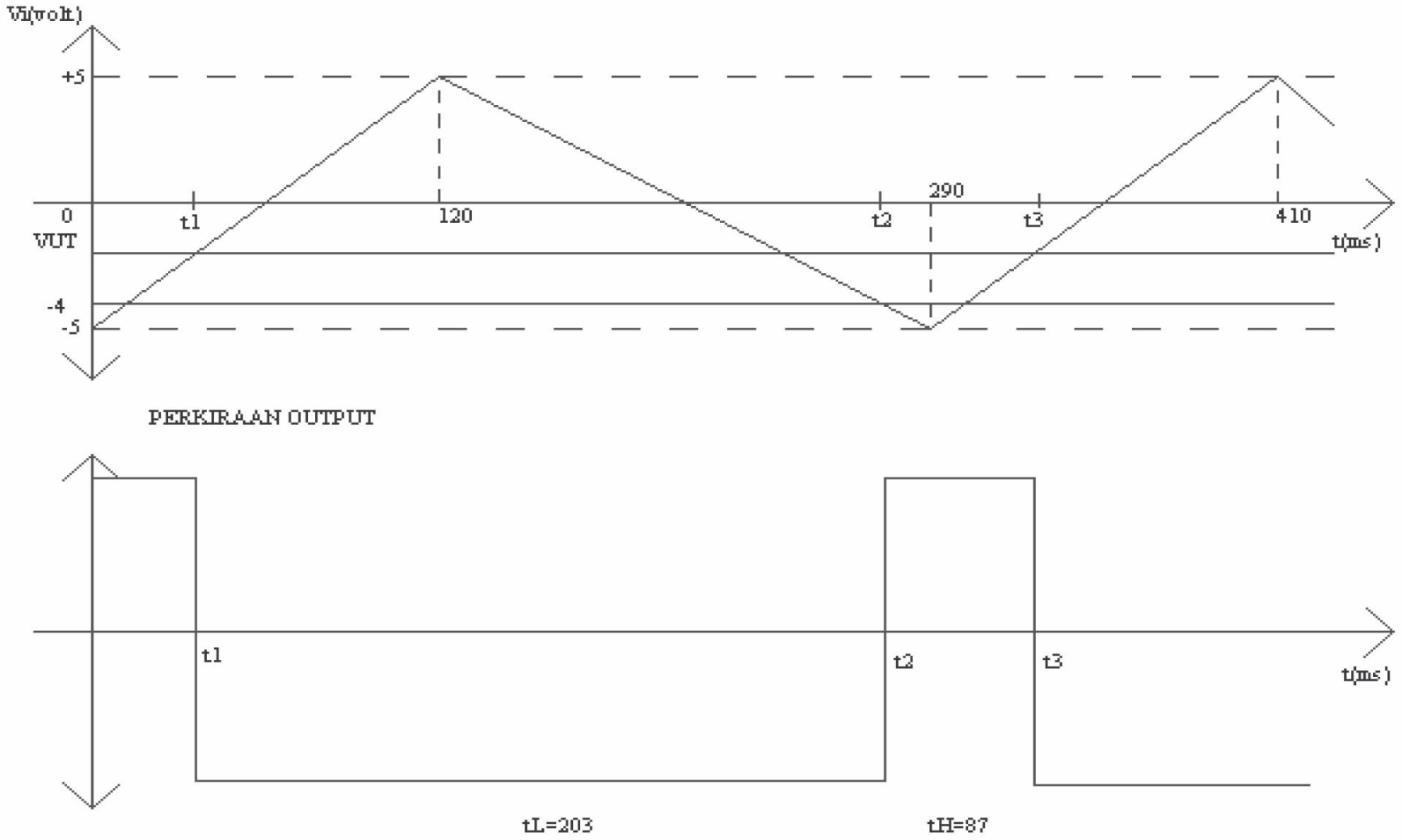
$t_H = 30\% \times 290 = 87\ \text{ms}$

$t_L = 70\% \times 290 = 203\ \text{ms}$

$$Vctr = \left(\frac{n}{n+1}\right).Vref$$

$$VH = \frac{2.Vsat}{n+1}$$

Dipilih: $V_{LT} = -4\text{volt}$



Untuk waktu: $120 < t < 290$: Persamaan: $Vi(t) = -\frac{10}{170}.t + c$

Pada saat $t = 140$, $Vi(t) = +5$ volt

sehingga: $5 = -\frac{1}{17}.(120) + c$

$$c = 5 + 7\frac{1}{17} = 12\frac{1}{17}$$

$$Vi(t) = -\frac{1}{17}.t + 12\frac{1}{17}$$

Pada saat $Vi(t) = VLT = -4$ volt maka $t = t2$

$$-4 = -\frac{1}{17}.t2 + 12\frac{1}{17}$$

$$\frac{1}{17}.t2 = 4 + 12\frac{1}{17}$$

$$\frac{1}{17}.t2 = \frac{273}{17} \quad \text{maka} \quad t2 = 273\ ms$$

$t3 = t2 + tH = 273 + 87 = 360$ ms

Untuk waktu: 290 < t < 410: Persamaan: $Vi(t) = \frac{1}{12}.t + c$

Pada saat t = 290, Vi(t) = −5 volt

$$-5 = \frac{1}{12}.(290) + c$$

$$c = -5 - 24\frac{2}{12} = -29\frac{1}{6}$$

sehingga: $Vi(t) = \frac{1}{12}.t - 29\frac{1}{6}$

Pada saat t = t3 = 360 ms, $Vi(t)$ = VUT

$$V_{UT} = \frac{1}{12}.(360) - 29\frac{1}{6} = 30 - 29\frac{1}{6} = \frac{5}{6} = 0{,}83 \text{ volt}$$

$$V_H = V_{UT} - V_{LT} = 0{,}83 - (-4) = 4{,}83 \text{ volt}$$

$$V_{ctr} = \frac{VUT + VLT}{2} = \frac{0{,}83 - 4}{2} = -1{,}59 \text{ volt}$$

$$n+1 = \frac{2.Vsat}{VH} = \frac{2.14}{4{,}83} = 58 \ldots\ldots n = 4{,}8$$

$$Vref = \frac{n+1}{n}.Vctr = \frac{4{,}8 + 1}{4{,}8}.(-1{,}59) = -1{,}92 \text{ volt}$$

Perbandingan R1 dan R2 apabila R2 = 10 K.

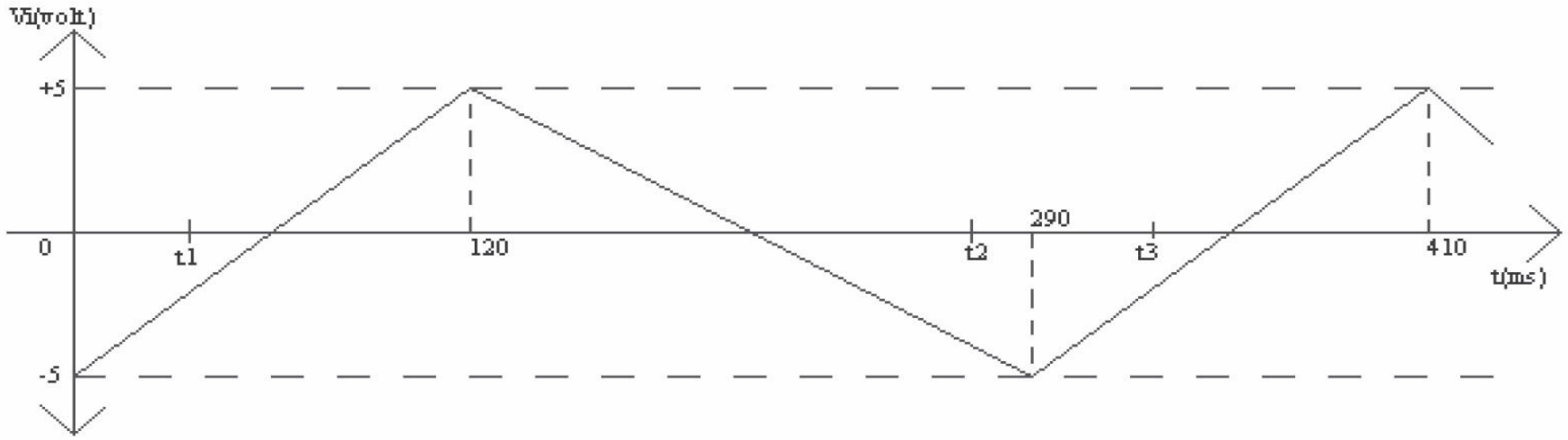
$$\frac{R2}{R1+R2}.(-V) = -1,92 \ldots\ldots \frac{10}{R1+10}.(-15) = -1,92$$

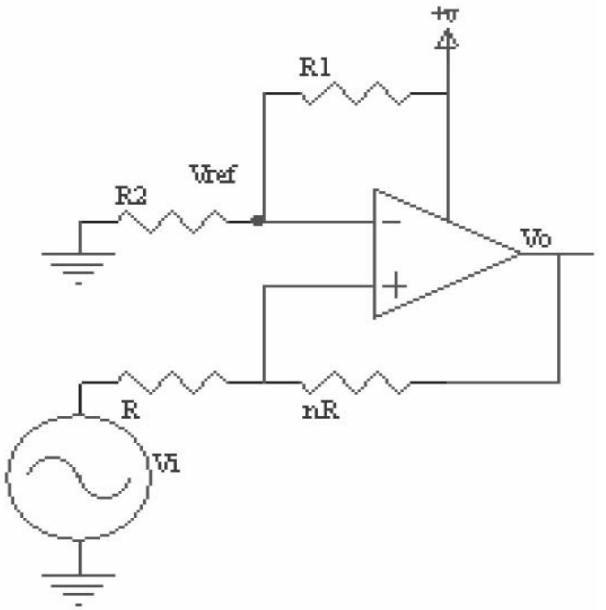
$$-1,92.R1 = -150 + 19,2$$

$$R1 = 68,125K\Omega$$

Jika R = 10 K maka nR = 48 K.

** Apabila jenis NIVLD dengan histeresis dan *duty cycle* = 30 % maka Vref = positif





$T = 290\ ms$

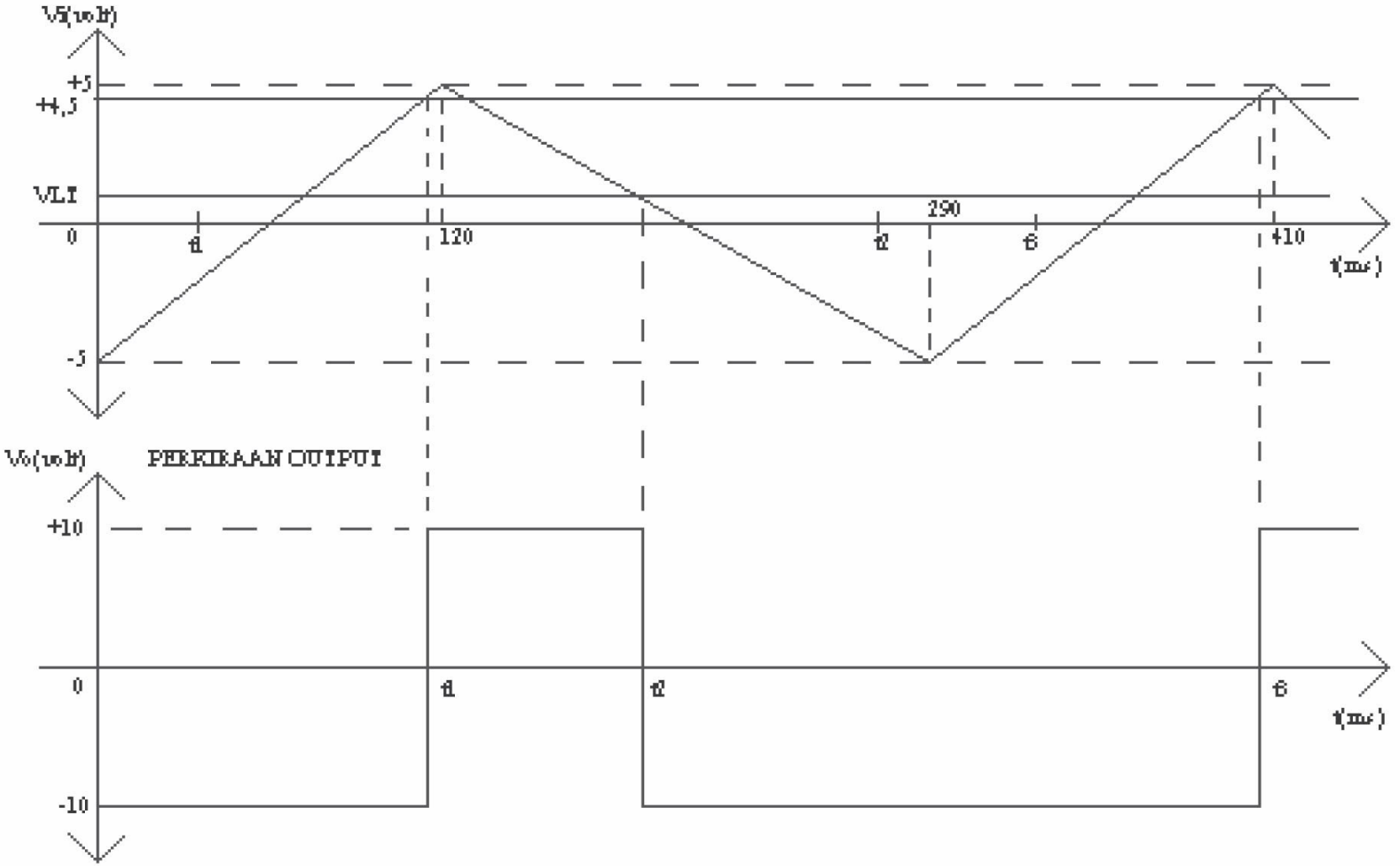
$t_H = 30\% \times 290 = 87\ ms$

$t_L = 70\% \times 290 = 203\ ms$

$$Vctr = \left(1 + \frac{1}{n}\right).Vref$$

$$VH = \frac{2.Vsat}{n}$$

Dipilih: $V_{UT} = +4{,}5$ volt



Untuk waktu: $0 < t < 120$: Persamaan:

$$Vi(t) = \frac{1}{12}.t + c$$

Pada $t = 0$, $Vi(t) = -5$ volt

Maka: $-5 = \frac{1}{12}.(0) + c$

$c = -5$

sehingga: $Vi(t) = \frac{1}{12}.t - 5$

Pada saat $t = t1$, $Vi(t) = VUT = 4{,}5$ volt

$V_{UT} = \frac{1}{12}.(t1) - 5$...maka... $\frac{1}{12}.t1 = 4{,}5 + 5 = 9{,}5$....dan.... $t1 = 114$ detik

Untuk $t2 = t1 + tH = 114 + 87 = 201$ detik

Untuk waktu: 120 < t < 290: Persamaan:

$$Vi(t) = -\frac{10}{170}.t + c$$

Pada t = 120, Vi(t) = +5 volt

sehingga: $5 = -\frac{1}{17}.(120) + c$

$$c = 5 + 7\frac{1}{17} = 12\frac{1}{17}$$

$$Vi(t) = -\frac{1}{17}.t + 12\frac{1}{17}$$

Pada saat t = t2 = 201 detik maka Vi(t) = VLT

$$V_{LT} = -\frac{1}{17}.t2 + 12\frac{1}{17}$$

$$V_{LT} = -\frac{201}{17} + 12\frac{1}{17}$$

$$V_{LT} = \frac{-201 + 205}{17} = \frac{4}{17} = 0{,}24 \text{ volt}$$

t3 = t2 + tL = 201 + 203 = 404 ms

$V_{UT} = 4{,}5$ volt

$V_{LT} = 0{,}24$ volt

$$V_H = V_{UT} - V_{LT} = 4{,}5 - (0{,}24) = 4{,}26 \text{ volt}$$

$$V_{ctr} = \frac{V_{UT} + V_{LT}}{2} = \frac{0{,}24 + 4{,}5}{2} = 2{,}37 \text{ volt}$$

$$n = \frac{2.Vsat}{V_H} = \frac{2.14}{4{,}26} = 6{,}57$$

$$V_{ctr} = \left(1 + \frac{1}{n}\right) Vref \ldots maka \ldots Vref = \frac{V_{ctr}}{1 + \frac{1}{n}} = \frac{2{,}37}{1 + \frac{1}{6{,}57}} = \frac{2{,}37}{1{,}15} = 2{,}06 \text{ volt}$$

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https://www.its.ac.id/telektro/id/beranda/